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Major factors to be considered when estimating the construction cost of placing fill in a flood plain are: preparation of the site; obtaining, placing and compacting the desired depth of fill; providing compensatory storage; variations in labor and equipment costs in different cities. Data are presented to facilitate estimating these factors.

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# COSTS OF PLACING FILL

# IN A FLOOD PLAIN

MAY 1975

The Hydrologic Engineering Center
Corps of Engineers, U.S. Army
609 Second Street
Davis, California 95616



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CONTENTS

# COSTS OF PLACING FILL IN A FLOOD PLAIN

## INTRODUCTION

The purpose of this study is to develop information on the costs associated with placing fill in a flood plain for residential development. This information is intended to be used only for making approximate or order of magnitude estimates of cost during preliminary planning and plan review and not as a substitute for detailed cost estimating. The study was sponsored by the Institute for Water Resources.

To develop the necessary information The Hydrologic Engineering Center contracted with three engineering firms in different regions of the country and asked them to develop cost information for their respective region. The firms performing this work were,

Bauer Engineering
Chicago, Illinois

Gennis, Gray and Justice
Sacramento, California

VTN Engineers
Metairie, Louisiana

Results from these studies are summarized below and the studies themselves are included in the Appendix of this report. Each firm contributed a unique perspective to the question, "what does it cost to fill in the flood plain?" and taken together they present the information necessary for approximating construction costs. In addition, important information is presented on engineering, environmental and legal implications of filling in of flood plain land.

## SUMMARY OF STUDY RESULTS

The major factors to be considered when estimating the construction cost of placing fill in a flood plain are: preparation of the site, that is, clearing and grubbing of existing vegetation and stripping of topsoil;

obtaining, placing and compacting the desired depth of fill at the site; providing compensatory storage for the natural flood plain storage lost by filling; and variations in labor and equipment costs in different cities around the country. All of these costs are important, should be included where applicable, and can be approximated from data presented in this report.

In addition to construction costs there are other important considerations - the change in conveyance capacity of the channel, the change in flood plain storage, the change in the existing flood plain environment, and the legal implications of altering flood plain land.

## Major Considerations in Estimating Construction Cost

Clearing and Grubbing - Where vegetation exists at the flood plain site, it should be removed before fill is placed. The type of vegetation to be removed, the type of soil available to support removal equipment, and the method of disposal are the major cost factors.

Stripping Topsoil - Where topsoil at the site is unsuitable as a foundation for fill, then it should be stripped and replaced with suitable material. Major cost factors are the deptn of topsoil to be stripped and the length of haul. If the material is respread and graded then this cost must be included.

Data for the cost of clearing and grubbing and for stripping of topsoil were developed by Bauer Engineering and are shown in Table 1. While these data are for general conditions and are based upon experience in Illinois they do provide an indication of the relative magnitude of this cost item and should be an adequate indicator. Where site conditions differ significantly from those for which these data were developed then the values should be adjusted accordingly.

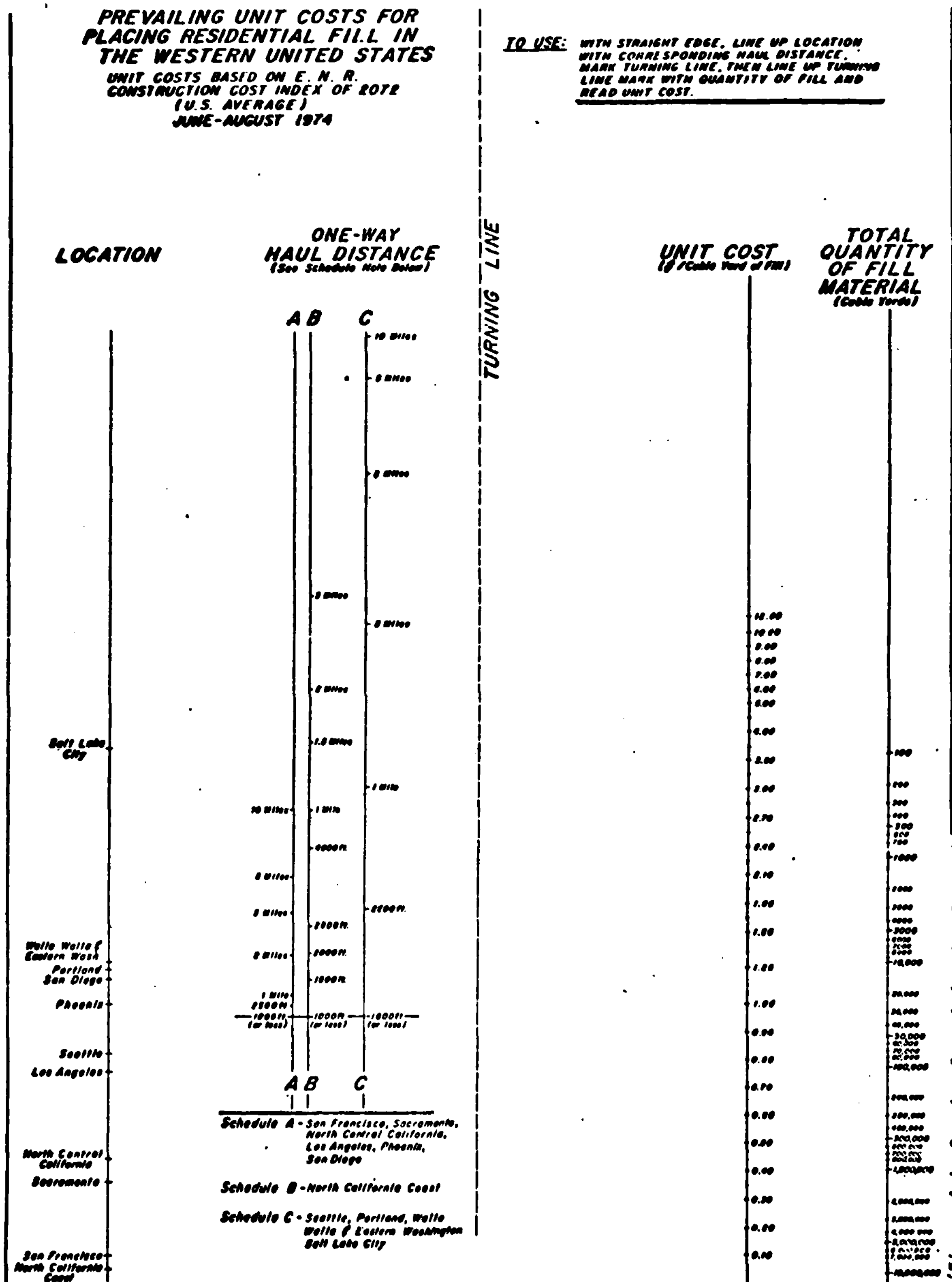

FIGURE 1a

(Figure 4 in Gennis, Gray & Justice Report)

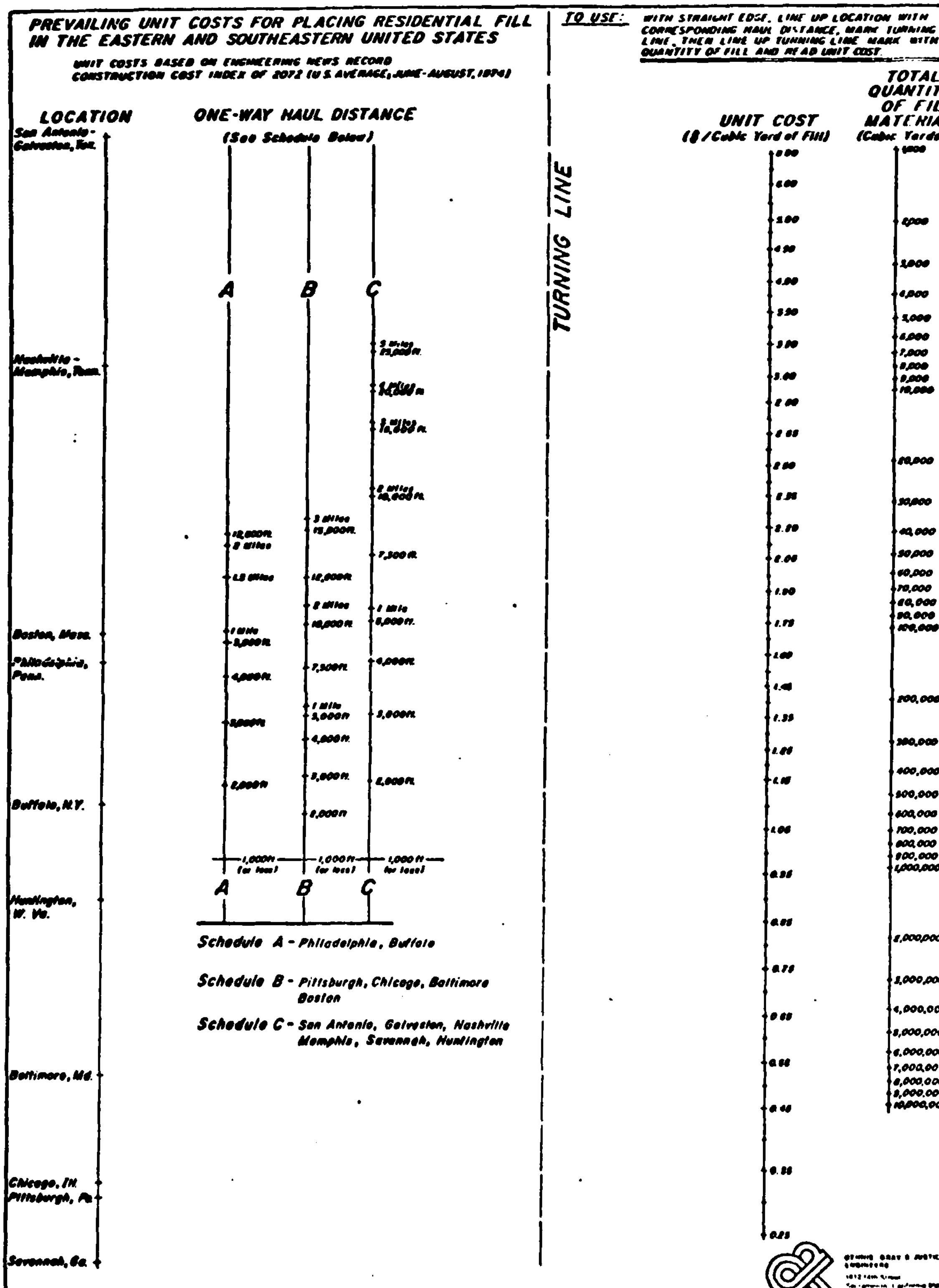


FIGURE 1b

Figure 6 in Gennis, Gray & Justice Report

Table 1: Cost of Clearing, Grubbing and Stripping of Topsoil Prior to Filling of Flood Plains in Dollars Per Acre

| Clearing and Grubbing | | | Stripping of Topsoil |
|---|---|---|---|
| norm | no vegetation | thick vegetation | |
| $ 6,800 | $ 5,800 | $ 7,000 | norm(1.5 ft. to be stripped) |
| $ 4,900 | $ 3,900 | $ 5,100 | 1.0 ft. to be stripped |
| $ 8,700 | $ 7,700 | $ 8,900 | 2.0 ft. to be stripped |
| $14,550 | $13,550 | $14,750 | 3.5 ft. to be stripped |

From - Bauer Engineering, "Guidelines for Filling Floodplains," April 1975.

Obtaining, Placing and Compacting Fill - Major factors which influence the cost of these items are: the cost of the fill, that is, whether there is a royalty charge; the haul distance from borrow to placement site; the quantity being hauled; the compaction requirements (assumed in this study to be 90% which is common for residential fill); and labor and equipment costs which vary with geographic location.

All three firms developed information for estimating the cost of obtaining, placing and compacting fill. There was general agreement in these data when labor and equipment cost variation, between different cities, was taken into consideration. Each firm presented their data in a somewhat different form, so to present a uniform technique covering all three regions the data were placed on a nomograph developed by Gennis, Gray & Justice Engineers (Figures 1a,1b). In some regions additional data was collected to provide a broader range of coverage and these are tabulated in an Appendix to the Gennis, Gray & Justice report.

Providing Compensatory Storage - In flood plains governed by state laws or local ordinances that require that flood plain storage eliminated by fill be compensated for, the cost of providing this compensatory storage should be included as a cost of placing fill. Table 2 summarizes the cost experience of Bauer Engineering in Illinois for providing compensatory

storage. These costs include land and construction costs for detention/ retention reservoirs as a means of providing this storage and serve as an indicator of the magnitude of this cost item. For storage to be truly compensatory it must have the same hydrologic and hydraulic effect as natural storage.

Table 2: Cost of Compensatory Storage
Dollars Per Acre of Flood Plain Filled

| Cost of Land | Average Depth of Fill (ft.)* | | | | |
|---|---|---|---|---|---|
| | 0 | 2 | 4 | 6 | 8 |
| $ 2,000/acre | 0 | 6,700 | 13,000 | 19,300 | 25,600 |
| $ 5,000/acre | 0 | 7,300 | 13,600 | 19,900 | 26,200 |
| $10,000/acre | 0 | 8,300 | 14,600 | 20,900 | 27,200 |

From - Bauer Engineering, "Guidelines for Filling Floodplains," April 1975.
*These average depths were modified by 2 feet to eliminate the 2-foot height above the 100-year design flood elevation assumed in the Bauer Engineering report and which did not enter the computations.

The data in this table were developed in the following manner. It was assumed the cost of compensatory storage includes $3,150 per acre-feet of fill for nonexcavation costs - site preparation, structures, pumps - and 20% of the flood plain land cost. Thus, the table value for flood plain land costing $2,000/acre and being filled 4 feet is 4 x 3,150 + .2 x 2000 or $13,000 per acre of flood plain filled. The nonexcavation cost ($3,150) and land cost (20%) were developed from projects described in Table 4 of the Bauer Engineering report.

Labor and Equipment Cost Variation - A given fill project will cost more in one location of the country and less in another, partly because of the difference in labor and equipment costs. This is illustrated in Figure 1. Various cost indices have been developed over the years to help estimators account for this variation. One popular index is that of Engineering News-Record, referred to as the ENR Construction Index.

ENR Indices are available on a monthly basis for twenty major cities of the country. Approximate costs obtained from Figure 1 can be applied to other locations and prices can be updated to current price levels using the ENR Construction Index. Other indices are available - some more representative of earthwork costs - and these may be used in a similar manner. The ENR Construction Index was selected because of its general use and because it was felt it would be sufficiently accurate for the purposes discussed here.

Example Computation

As an example of the computational procedure for estimating costs of placing fill in a flood plain, assume the following hypothetical conditions.

- 10 acres of flood plain area in the vicinity of Sacramento, California
- 3-foot average fill depth below the 100-year flood elevation
- 48,400 cubic yards of fill required
- 90% compaction required (normal requirements for residential fill)
- little vegetation in the area
- 1.0 feet of topsoil to be stripped
- 3-mile one-way haul distance to placement site (no royalty charge)
- $5,000/acre approximate land value
- minimal natural wildlife or habitat
- compensatory storage is required

Cost of Clearing and Grubbing and Stripping Topsoil from Table 1

Cost = $3,900/acre

Cost of Obtaining, Placing and Compacting Fill from Figure 1 at Sacramento, 3-mile haul distance and 48,400 cubic yards

Cost = $1.80/cu.yd.

Cost of Compensatory Storage from Table 2 interpolating between 2 feet and 4 feet,

Cost = $10,450/acre

### Labor and Equipment Cost Variation

The ENR Index does not cover Sacramento, so no adjustment in cost of clearing and grubbing and stripping of topsoil will be made. Also, because Sacramento is one of the locations in Figure 1, no adjustment need be made for cost of obtaining, placing and compacting fill.

### Costs in March 1975 Dollars

Figure 1 is based upon average 1974 dollars - an ENR Construction Index of 2072. The average index for March 1975 was 2128.

### Total Cost of Placing Fill

| | | |
|---|---|---|
| Clearing and Grubbing and Stripping Topsoil | \$3,900/acre x 10 acres | = \$ 39,000 |
| Obtaining, Placing and Compacting Fill | \$1.80/cu.yd. x 48,400 cu.yd. | = \$ 87,120 |
| Compensatory Storage | \$10,450/acre x 10 acres | = \$104,500 |
| | Total Cost | \$230,620 |
| | or | \$ 23,000/acre |
| Cost in March 1975 Dollars | $\frac{2128}{2072} \times 23,000$ | = \$ 23,600 |

## Engineering, Environmental, and Legal Aspects of Filling

Filling in of flood plain land has a potential impact on the conveyance capability of the stream, the availability of natural flood plain storage, ground water recharge rates and the natural ecosystem (Bauer Engineering, page 13). While fill would generally be placed outside the main floodway the conveyance capability of the flood plain during flood flows is none the less reduced. The result is an increase in water surface elevation. Flood plain occupants in residence before fill placement could experience higher flood levels than previously occurred as a result of the fill.

Natural flood plain storage has an attenuating effect on flood flows similar to that of storage reservoirs. The loss of flood plain storage

by filling can result in higher flood flows in downstream reaches, especially if fill placement is extensive. The replacement of natural storage by compensatory storage may be difficult because not only is the total volume of significance, but so is the time and manner in which it comes into operation.

Another potential impact is on the availability of ground water. Flood plains often serve as prime recharge areas for shallow aquifers and the recharge rate influences the amount of water available for pumping. Altering the ground surface above these aquifers may cause changes in the recharge rate with a corresponding long term reduction in available ground water.

The natural ecosystem, that is, the ecosystem existing in the flood plain prior to placing fill, will be modified by placing fill. The extent of this modification and its relative importance with respect to environmental features is site dependent. Various attempts have been made to estimate an economic value of the ecosystem and from this the economic loss or gain due to its modification. Whether or not an economic value is estimated, the changes - quantitative and qualitative - should be recognized.

An examination of several flood plain ordinances and court decisions by Bauer Engineering presents information on the current legal activity concerned with regulating filling in of flood plain land. This activity includes establishment of permit procedures, prohibiting alteration of floodway capacity, requiring compensatory storage, assessing the suitability of flood plain land for different uses, and preventing unreasonable changes in the natural lateral and vertical drainage flow. This legal activity raises the question of the propriety of filling and whether filling, without consideration of all effects, is contrary to sound management practice.

## STUDY CONCLUSIONS

Information is presented in this report for the cost of placing fill in a flood plain. This information should be useful to planners and others for determining approximate construction costs of placing fill. While the data presented are derived from specific bids or engineer's estimates they are presented here for general use and as such some of the site specificity upon which they were originally based is lost. The data presented for approximating the cost of obtaining, placing and compacting fill is relatively complete. The data for clearing and grubbing, stripping topsoil, and compensatory storage is based upon experience in Illinois. It would be desirable to obtain similar data in other regions of the country, however, these data serve as a useful reference point.

In addition to construction costs there are other engineering, environmental, and legal aspects of filling which should be addressed. Filling can reduce the conveyance capability, raising water surface elevations; reduce available flood plain storage, raising water surface elevations downstream; reduce ground water recharge rates; modify the existing ecosystem; conflict with laws and ordinances intended to manage flood plain land use. A detailed discussion of these effects is beyond the scope of this particular study, but should not be beyond the scope of any planning study proposing flood plain fill.

# GUIDELINES
# FOR FILLING FLOODPLAINS

A Bauer Engineering Report

April 1975

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**BAUER ENGINEERING, INC.**

20 NORTH WACKER DRIVE • CHICAGO, ILLINOIS 60606 • TELEPHONE (312) 368-7900

April 15, 1975

Mr. William S. Eichert, Director
Hydrologic Engineering Center
Sacramento District
Corps of Engineers
Brinley Building
609 Second Street
Suite M
Davis, California 95616

Dear Mr. Eichert:

We are pleased to submit this final report on guidelines for the placement of fill in a flood plain to protect against a 100-year flood.

Thank you for the opportunity to perform this service. We will welcome any questions the report may raise.

Sincerely,

Clint J. Keifer

Clint J. Keifer
President

CJK/pr

Enc.

# I. INTRODUCTION

The objective of this report is to present a set of guidelines for use by Project Reviewers at the OCE level in evaluating the cost of placing fill in a floodplain in order to elevate the entire plain above the level that would be reached by a 100-year flood. The assumption is that the filled area would be used as a site for new realty development.

The construction costs of preparing the site and placing the fill are quantified in these guidelines. However, a number of impacts of floodplain filling and their implications also must be addressed. These include the loss of floodplain storage, the reduction of groundwater recharge, and the damage done to ecosystems -- items difficult to quantify in terms of the values traditionally assigned in cost evaluations. Furthermore, legal implications arising from the growing practice of state and local government regulation of land use in flood-prone areas must be taken into account. Therefore, this report includes a resume of some experience relating to the legal aspects of floodplain filling.

## II. FACTORS INFLUENCING COSTS

The formulation of specific cost guidelines must begin with certain assumptions regarding the nature of the fill and the procedures used in placing the fill in the floodplain.

There are two principal methods of filling in a floodplain. The entire plain can be raised above the level of the 100-year flood, or the sites of structures called for by the development plan can be raised above the 100-year flood level while the intervening plain is not raised. The assumption made in this report is that the floodplain would be raised uniformly. Hence, the stated cost is the maximum cost of filling in a floodplain.

The filling in of a floodplain can be either unplanned or planned. Many small areas are filled in an unplanned manner. In such cases, the owner of the property solicits fill and accepts almost anything that is available. The result is a heterogenous mixture of building rubble, spoil from construction projects, and ashes in the fill. One possible consequence is differential settling of the fill due to poor compaction. This filling method may seem inexpensive, but substantial costs may be incurred in rectifying problems that arise after the development has been placed on the fill. Also, leachate from such fills can cause water pollution.

The writers of this report believe that unplanned fills will become rarer as state and local regulatory agencies enforce regulations to prevent unwise use of floodplains. So the report will not present cost guidelines for unplanned fills. The guidelines presented here apply only to the planned filling of floodplains, and are a composit of cost estimates for clearing and grubbing the site, stripping topsoil, obtaining fill, and

placing and compacting the fill in the floodplain. Each of these cost elements is discussed briefly below.

## Clearing and Grubbing

Clearing and grubbing to remove existing vegetation should be carried out before the flood plain site is filled.

The type of existing vegetation greatly influences these costs. For example, if the vegetation consists only of grass, the clearing and grubbing would not be necessary because the stripping of the topsoil would remove it. If the vegetation consists of a great number of large trees and brush, clearing and grubbing would be a major operation. For this report, existing vegetation will be assumed to consist of scrub brush with some medium-sized trees.

Another major factor in the cost of clearing and grubbing is whether the ground in the area will support heavy machinery. If not, more expensive methods will have to be utilized. In such unstable soil areas, not only will clearing and grubbing be more expensive but all associated development activities will also be increased in cost. For the purposes of this study, it is assumed that only flood plain containing favorable soil and geologic conditions will be filled.

The method of disposal of the cleared vegetation is a significant cost item. Burning of this material was the usual technique in the past. However, present air pollution laws all but eliminate this as an option. Alternate methods include chipping and spreading on site, burial on site, and off-site disposal. Chipping and on-site spreading will be the assumed method of determining costs in this report.

Stripping Topsoil

Topsoil and other soils found in flood plains may not be suitable for foundations. Soils that are normally high in organic content should be stripped off the surface. The amount of these types of soils existing in a flood plain is the result of a number of factors including, climate, topography, and underlying geology. If the depth of this type of soil is not known for a particular flood plain, rough estimates based on experience in Illinois can be made on the basis of topographic data. For steep gradients of the flood plain, the depth of topsoil required to be removed would be about 1 foot. For intermediate and gentle slopes 2.0 feet and 3.5 feet respectively would have to be removed. These figures should be used with care because a number of additional factors could alter them significantly.

The topsoil is usually stripped from the fill site and stockpiled to be used for landscaping and seeding purposes. Variables in the cost of this operation include depth of topsoil and length of haul to the stockpile. It is assumed all topsoil is replaced on finished grade. The costs presented for this item include stripping, stockpiling, respreading, and grading of the topsoil during landscaping of the final project based on an assumed 1.5 feet of topsoil to be stripped.

## Obtaining Fill

The cost of fill material delivered to the site is a major expense that is influenced by a number of variables. Where the fill is obtained, how it is excavated, and the method of hauling all influence the costs. Because many flood plain regulations prohibit the aggravation of upstream and downstream flood problems, the filling in of a flood plain must preserve the natural storage and the carrying capacity of the stream. This is frequently done by cutting and filling in the flood plain. Such an approach makes good quality, homogeneous fill material readily available at the site to be filled. Other sources of good quality fill would be from large excavation projects -- foundations for major structures -- or from borrow pits. In some environments the borrow pit will become a lake which has secondary development benefits.

With respect to hauling, two cost estimates are made. The first estimate assumes the hauling of the fill material on public roads. In this situation the fill must be placed in trucks and hauled to the project site. This would normally require a shovel-type machine at the excavating site. Many factors must be considered in determining the type and size of machinery to be used at a particular job. This study will assume bulldozers and front-end loaders for excavation machinery.

The second estimate assumes only on-site hauling. Hence, excavation will be in the vicinity of the fill area. In such situations, scrapers will be used for fill excavation and on-site hauling. For purposes of this report, when the distance of haul is greater than 4,500 feet it is assumed that hauling must be over public road. When the haul distance is less than 4,500 feet, on-site hauling is assumed.

## Placing and Compacting

The method of placement and compaction is assumed to consist of spreading the dumped material by dozer in 9" lifts and compaction of each lift by sheeps-foot roller. Compaction is assumed to be at least to 90% density for this study.

## Providing Compensatory Storage

One factor that has a significant effect on the cost of filling a flood plain is a requirement to provide compensatory storage. In many areas, compensatory storage is required to replace the volume of floodwater storage that will be eliminated by the flood plain fill.

This storage can be provided in retention or detention reservoirs. But the compensatory storage must have the same effect on the flood event that the replaced natural storage had. Compensatory storage that fills during the first period of the flood event will have little effect on the crest stages. Thus such storage must be designed to handle this problem by pumping or through specially designed inlet and outlet structures. Such facilities increase the operating and maintenance costs of the compensatory storage.

The cost of land is a major element in determining the cost of providing compensatory storage. For purposes of this report, the cost per acre in small urban areas is estimated to be $2,000, in moderate urban areas $5,000, and in metropolitan areas $10,000. If land costs are known for a particular area, these should be used.

It will be assumed that a retention or detention reservoir will be used for compensatory storage and also that such a facility will occupy

20 percent of the land area to be filled and developed. Thus a 50 acre development will require 10 acres for compensatory storage.

The construction cost of compensatory storage will consist of excavation, site preparation, and necessary structural considerations. It is assumed that the cost of excavation is included with the costs of obtaining fill.

## III. COST EXPERIENCE

The costs presented in this section are based on an ENR index of 2200 and were developed from recent estimated costs and actual bids on construction projects that are analogous to the filling of flood plains. Bid tabulations for these projects are presented in the Appendix.

This section presents unit costs for each of the factors discussed in Section II. Also presented are the assumptions upon which these costs are based and how much the costs will vary based on different assumptions. The tables in this section summarize the information to expedite the estimating of costs under various conditions.

### Clearing and Grubbing

Norm unit cost - $1,000/acre

Norm conditions clearing, grubbing and chipping of vegetation consisting of medium sized trees and some brush.

Modifying conditions - no trees or brush, reduce by 100 percent
- large trees or heavy brush, increase by 20 percent

### Stripping Topsoil

Norm unit cost - $5,800/acre

Norm conditions - 1.5 feet depth must be stripped, costs include stripping, stockpiling, replacing and grading to landscape finished project.

Modifying conditions - if 2.0 feet must be stripped increase by 33 percent
- if 3.5 feet must be stripped increase by 135 percent

### Obtaining Fill

Road Haul Necessary

Norm unit costs - \$2.90/cubic yard

Norm conditions - 5 mile haul distance, bulk factor of 1.4, clay-type material.

Modifying conditions - haul distance for each mile less than 5 miles subtract \$0.25/cubic yard.

On-Site Haul

Norm unit cost - \$1.20/cubic yard

Norm conditions - clay-type material, 1500 feet haul distance

Modifying conditions - longer haul, increase by \$0.18 for each additional 1,000 feet haul distance up to 4,500 feet haul.

### Placing and Compacting Fill

Norm unit cost - \$0.80/cubic yard

Norm conditions - clay-type material, 90% modified proctor density

### Providing Compensatory Storage

Norm unit cost - \$3,150/acre-foot

Norm conditions - excavation charged to the filling price
- includes construction costs of structures.

### Cost Tables

To calculate the cost of filling in a flood plain, one must first estimate the cost of clearing, grubbing and stripping of topsoil. Table 1 presents the costs per acre for these elements for a variety of conditions.

Table 1: Cost of Clearing, Grubbing and Stripping of Topsoil Prior to Filling of Flood Plains in Dollars Per Acre

| Clearing and Grubbing | | | Stripping of Topsoil |
|---|---|---|---|
| norm | no vegetation | thick vegetation | |
| $ 6,800 | $ 5,800 | $ 7,000 | norm(1.5 ft. to be stripped) |
| $ 4,900 | $ 3,900 | $ 5,100 | 1.0 ft. to be stripped |
| $ 8,700 | $ 7,700 | $ 8,900 | 2.0 ft. to be stripped |
| $14,550 | $13,550 | $14,750 | 3.5 ft. to be stripped |

Table 2 tabulates the cost of obtaining fill, placing it in the flood plain, and compacting it for depths ranging from 2 feet to 10 feet. In Table 3, the cost of compensatory storage in dollars per acre of flood plain is presented for depths of fill ranging from 2 feet to 10 feet.

To establish the cost of planned filling of a flood plain, one simply extracts from the three tables the costs associated with a given situation. To illustrate, assume that a flood plain site has thick brush and contains 2.0 feet of topsoil that must be stripped; the fill must be moved on roads 4 miles and will have an average depth of 6 feet; and the site is located in a metropolitan area. The costs of filling in one acre of flood plain in this example will be:

| | |
|---|---|
| from Table 1 | $ 8,900 |
| Table 2 | 33,400 |
| Table 3 | 14,600 |
| | $56,900/acre |

Table 2: Unit Cost for Obtaining Fill, Placing it in Flood Plains and Compacting it in Dollars Per Acre

| Type of Operation | Average Depth of Fill (Ft.) | | | | |
|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 |
| On Site Haul | | | | | |
| Norm (1500' haul) | 6,450 | 12,900 | 19,350 | 25,800 | 32,300 |
| 2500' haul | 7,000 | 14,100 | 21,100 | 28,100 | 35,200 |
| 3500' haul | 7,600 | 15,200 | 22,800 | 30,500 | 38,100 |
| 4500' haul | 8,200 | 16,400 | 24,600 | 32,800 | 41,000 |
| Road Haul | | | | | |
| Norm (5 mile haul) | 11,900 | 23,900 | 35,800 | 47,750 | 59,700 |
| 4 mile haul | 11,100 | 22,300 | 33,400 | 44,500 | 55,700 |
| 3 mile haul | 10,300 | 20,650 | 31,000 | 41,300 | 51,600 |
| 2 mile haul | 9,500 | 19,000 | 28,600 | 38,100 | 47,600 |
| 1 mile haul | 8,700 | 17,400 | 26,100 | 34,800 | 43,600 |

Thus, the planned filling of a flood plain with the preceeding characteristics so as to raise development sites above the 100-year flood will cost $56,900 per acre. Similar estimates can be gotten from the tables for a range of conditions. Within the context of these tables the lowest cost of filling a flood plain would be $17,050 per acre and the highest cost would be $101,650 per acre.

Table 3: Cost of Compensatory Storage
Dollars Per Acre of Flood Plain Filled

| Cost of Land | Average Depth of Fill (ft.) | | | | |
|---|---|---|---|---|---|
| | 2 | 4 | [illegible] | 8 | 10 |
| $ 2,000/acre | 0 | 6,700 | 13,000 | 19,300 | 25,600 |
| $ 5,000/acre | 0 | 7,300 | 13,600 | 19,900 | 26,200 |
| $10,000/acre | 0 | 8,300 | 14,600 | 20,900 | 27,200 |

NOTE: It is assumed fill will be placed to a height of 2 feet above the 100-year design flood elevation.

## IV. OTHER ENVIRONMENTAL IMPACTS

The filling in of flood plains has a potential impact on the availability of groundwater, the availability of natural flood plain storage, and on the diversity of natural ecosystems. Such impacts cannot always be stated in terms of specific economic effects. Nevertheless, it is possible to identify potential impacts and to suggest what the economic impacts might be. Each of these impacts are discussed briefly in the section and preliminary economic values have been assigned to them.

### Impact on Groundwater

The filling of flood plains can diminish the availability of groundwater. In many cases, this impact is ignored. Northeastern Illinois can be used to illustrate the potential damage fill in flood plains could cause to a groundwater supply. Many of the flood plains in northeastern Illinois are underlain by surficial sand and gravel aquifers. These surficial sand and gravel deposits serve as prime recharge areas for what is termed the shallow aquifers. Such flood plains are prime recharge areas for several reasons. First, the relatively high permeability, of the sand and gravel deposits allows water to infiltrate to shallow aquifers. Second, a source of water for recharge, the perennial stream in the flood plain, is available. The shallow aquifers are defined as the sand and gravel and dolomite aquifers combined. The shallow aquifers are the major source of groundwater for northeastern Illinois. In Du Page County, the floodplains of the East and West Branches of the Du Page River and Salt Creek are the prime natural recharge areas. In 1972, 39.7 mgd or 70 percent of the total pumpage of 56.6 mgd was derived from the shallow aquifers. Potential yield of the shallow aquifers is 42.0 mgd, 30 mgd from the glacial drift and 39.0 mgd from the dolomite. The filling of a flood plain

to gain development sites will decrease the recharge capability of the flood plain.

Natural recharge rates in flood plains underlain by sand and gravel have considerably higher recharge rates than the surrounding uplands where the uplands are underlain by more impermeable types of glacial drift. Such a geologic setting is frequently the case in Northeastern Illinois. For example, in Du Page County the recharge rate for the glacial aquifer underlying the flood plains of the East Branch and West Branch of the Du Page River ranges as high as 1,000,000 gpd/$mi^2$ compared to an average of 140,000 gpd/$mi^2$ on the uplands.

The reduction of natural recharge and potential artificial recharge sites by filling of flood plains will have an impact on groundwater availability. Given the present pumpage rates in major metropolitan areas, the preservation of flood plains as recharge areas for the shallow aquifers is of great importance.

## The Value of Natural Flood Plain Storage

Fill in a flood plain reduces the ability of the flood plain to store floodwaters. This issue has been addressed under the heading of compensatory storage. In heavily urbanized areas, conflicts between human occupance and floodwater storage exists on flood plains. In such instances alternative storage space for the floodwater must be provided. These costs are presented in Table 4.

Table 4: Construction Costs for Floodwater Storage Projects

| Project | Storage Acre-Ft. | Construction Cost | Cost Per Acre-Foot |
|---|---|---|---|
| Hillside 1/ Storm Retention | 75 | $ 693,798 | $ 9,250 |
| Kingery West 2/ | 90 | $ 453,115 | $ 5,034 |
| SCS Estimates 3/ | | | |
| Com. Edison Site | 380 | $1,614,000 | $ 4,250 |
| RR Yard Site | 440 | $1,983,000 | $ 4,506 |
| Addison Creek Estimates 4/ | | | |
| Lake Street Site | 130 | $2,320,000 | $17,850 |
| RR Avenue Site | 54 | $ 775,000 | $14,350 |
| Cemetery Site | 81 | $1,085,000 | $13,400 |

1/ - Metropolitan Sanitary District of Chicago Project-Bid Fall 1974.

2/ - Du Page County Forest Preserve Project-Bid Summer 1974.

3/ - Soil Conservation Service Report-Engineers Estimate Fall 1974.

4/ - Bauer Engineering, Inc. Report for Illinois Department of Transportation-Engineer's Estimate.

## Impacts on Floodplain Ecosystems

The filling of a floodplain often may replace the natural floodplain ecosystems. Estimates of value are at best dependent upon the prevailing value system of the society, which is in part subjective. Even in the physical structures we value in our historical context (e.g. -- a picturesque courthouse in the town square), meaningful estimates are difficult; in the world of nature, they rarely have been attempted.

Conservationists and ecologists often assume that any natural area of exceptional value in their eyes should also seem priceless to all others involved in land use decisions. As a first approach at standardizing methods of estimating economic value for different natural ecosystems, Howard Odum has suggested that the common energy component, the calorie, be used as a basis for comparison. Any given ecosystem can be viewed as a model constructed of certain components (i.e. -- producers, consumers, decomposers) through which energy flows and is converted in form. At each step in the process some energy is lost as heat, some energy is stored, and some is used to decrease the entropy of the system. Odum arbitrarily set a value of $1.00 per 10,000 kilo-calories. This value, it should be noted, is high -- more than double that of electric power in 1974 ($0.465) and more than sixteen times that of natural gas ($0.06). Odum then measured this expensive energy by equating 4.5 kilo-calories to one gram of dry weight in terrestrial plants. By estimating 10 million grams of biomass produced per acre of cat-tail marsh, a value of $4,500 per acre was put on the ecosystem. The replacement cost for a 100-year period at 7.5 percent interest would be $455,000 per acre with an annual loss of $34,125 per acre.

The value thus assigned to the energy produced by vegetation is impressive. Although many might judge it excessive, it does constitute

a first approximation of an answer to a problem that will have to be dealt with in the modern world. For centuries the most common method of valuing ecosystems was simple application of current market values of the land in terms of dollars. For example, government agencies, such as a park district, sets a value on an ecosystem when the district purchases a site of natural beauty to preserve it. This value almost always represents the cost of the land alone; the cost of replacing the ecosystems is not considered. But valuation methods that were acceptable half a century ago, or even twenty years ago, are no longer adequate to satisfy the current popular concern over the environment's impress on our lives. As public decision-makers grapple with such intangibles as beauty and peace of mind, it surely will be seen that no one standard dollar-equivalent (be it Odum's or another's) will fairly serve all ecosystems. Even similar ecosystems, differently located, will be found to have different values. And the scientific literature already shows there are cases where artificial intervention actually encourages a healthier ecosystem than the one that originally existed in nature. Considering the multitude of difficulties blocking the way to reasonable valuation of ecosystems, it is encouraging to know that at least a crude basis for a mathematical model has been laid. If this report stimulates efforts toward refinement of the model, the report writers will be content.

## V. LEGAL ASPECTS OF THE FILLING IN OF FLOOD PLAIN LAND

The filling in of flood plain land is a generally accepted method of protecting structural land uses from the damages associated with flood water. It serves to raise buildings and other structures above the elevation that the flood waters could reasonably be expected to reach. One of the major consequences of filling is a reduction of the capacity of the flood plain to store flood water. This then often leads to increased flood stages elsewhere along the stream.

Because filling is most commonly associated with flood plain and wetland areas, almost by definition, it is an activity that is often subject to regulation by flood plain management ordinances. When it is regulated, it has generally been done by the clauses of ordinances which prohibit any activity which could possibly have adverse effects on the storage capacity of the flood plain. This is all well and good as far as preservation of the storage capacity function of the flood plain is concerned. There are, however, other major functions and values of the flood plain and wetland ecosystems which also need to be protected. The function of groundwater recharge is of major importance, particularly in parts of the country that depend on groundwater for their municipal and private water supplies. The value of the natural flora and fauna of these ecosystems is also significant, and as other portions of this report indicate, is beginning to be able to be quantified. This is, of course, of great significance for cost-benefit analysis. It is important, however, that these values are considered in the evaluation of proposed land use changes, whether quantitatively or otherwise.

An examination of several flood plain ordinances and court decisions will illustrate the various approaches to flood plain management, and different ways of regulating fill.

The Division of Water Resources of the Illinois Department of Transportation has recently enacted regulations based on its authority to "define flood plains and to establish a permit procedure for regulating construction within the such defined flood plains". Rule 2.3 states that no construction or changes in the flood plain are lawful without a permit from the Department. Permits are ordinarily granted for construction which does not have significant flood damage potential and which will not significantly increase present or future flood damages. No activity will be permitted which will cause significant increases in flood stage or velocity. This ordinance does not specifically refer to the activity of filling, but the above requirements for a permit make it implicit that where filling may cause increases in flood stages or velocity, it will not be permitted. Compensatory storage, which provides alternative flood water storage where filling is occurring, will presumably be permitted when it can be shown that it will adequately compensate for the area being filled. The ordinance is clearly concerned with the function of flood water storage and flood flows, but it neglects the other values of flood plains and wetlands.

The model ordinance prepared by the Illinois Department of Local Government Affairs takes a similar approach. It generally prohibits any use which could adversely affect the capacity of drainage channels of floodways. Any use which would require fill would have to satisfy the conditions for a special use permit, which states that no use, including fill, will be allowed which, alone or in combination with existing or future uses, unduly affects the capacity of a floodway or increases flood heights. Specifically regarding fill, Rule 4.32 (1) states that any fill must be shown to have a beneficial purpose, and the amount should be no more than necessary to achieve that purpose. There is no specific requirement for compensatory storage. No reference is made to the value of the flood plain and wetland ecosystem being preserved in their natural states.

The Suggested Flood Damage Prevention Ordinance prepared by the Northeastern Illinois Planning Commission (NIPC) for local governments permits occupation only of the floodway fringe under certain specified conditions. The principal restriction is that any volume of space which is occupied by a structure or fill must be compensated for and balanced by at least an equal volume of excavation taken from below flood base elevation. Thus, this ordinance specifically requires compensatory storage when the natural capacity of the flood plain is being infringed on. Several of the local governments in the region have apparently adopted the principle of compensatory storage into their own ordinances, for example, Downer's Grove, Lombard and McHenry County. While this approach sets more stringent requirements for filling, the concern is still limited to controlling the quantity and velocity of flood water flow.

The flood plain regulation policies of Michigan, Minnesota and Wisconsin take approaches similar to the Illinois ordinances. Emphasis is placed on the capacity to store flood water without a view to the broader implications of flood plain management. The State of Michigan's Subdivision Control Act of 1967 (P.A. 288), in Section 194, prohibits construction in the flood plain district without approval of the Water Resource Commission. Alteration may be permitted if the land's drainage capacity will not be adversely affected. P.A. 167 authorizes the Water Resource Commission to regulate alterations of natural and/or present water courses of all rivers and streams to assure that the channels and floodways are kept free of interferences or obstructions which would cause any undue restriction of the capacity of the floodway. It can be inferred from the wording of the provision that filling which would reduce the capacity of the floodway to store and discharge flood water would not be allowed without some action which would compensate for the decreased capacity.

The Sample Flood Plain Zoning Ordinance for Local Units of Government, prepared by the Minnesota Department of Natural Resources, states that encroachments on the flood plain shall not cause an increase in the flood stage in any given reach of greater than 0.5 foot. Fill will be allowed in the floodway under a conditional use permit. Criteria are that the fill must have a proven beneficial purpose, and that the amount is no more than necessary to achieve that purpose. No mention is made of compensatory storage.

The Model Ordinance associated with Wisconsin's Flood Plain Management Program prohibits any fill, obstruction, etc.. that acting alone or in combination with existing or future similar works could adversely effect the efficiency of the capacity of the floodway. While not specifically requiring compensatory storage, this provision seems to imply that if it would provide acceptable storage capacity, it might permit the placing of fill in the floodway. As with the other ordinances with this type of regulation, the final decision on the legality of filling would rest with the local officials who administer the ordinances, and, perhaps, the judicial system which may be called upon to interpret them.

A different approach toward flood plain management is being taken in DuPage County, Illinois. The ordinance now in effect there is based upon a broader concept of the importance of flood plains and wetlands. Rather than seeing the problems of flooding from a purely engineering viewpoint, it looks at flooding from the perspective of land use and the natural suitability of the environment for different uses. The following criteria and purposes of the ordinance express the philosophy behind it:

a. To consider flooding and drainage problems as space allocation or land use problems and to the degree practicable allocate the natural storage space -- flood plains and wetlands -- for this purpose.

b. To use flood plains and wetlands for land use purposes which are compatible with their physical conditions thereby preventing the creation of new flood and drainage problems.

c. To avoid the increase of upstream and downstream flood risks by preventing increased runoff and a redistribution of flood waters.

d. To preserve and possibly enhance the quantity of groundwater supplies by maintaining open and undisturbed prime natural groundwater recharge areas.

e. To preserve and possibly enhance the quality of ground and surface water resources by helping to control excess infiltration into sanitary sewer systems and by preventing the location of septic systems and mixed fills in unfavorable physical environments.

f. To preserve distinctive flood plain and wetland flora and fauna.

g. To consider flood plain and wetland areas in density consideration in zoning and subdivision determinations.

h. To lessen or avoid the hazards to persons and damage to property resulting from the accumulation or runoff of storm or flood waters, as essential for the health, safety and general welfare of the people of DuPage County, in accordance with Chapter 34, Section 3151 of the Illinois Revised Statutes.

In addition to being oriented to prevent hazards to life or property by appropriating the necessary storage area on the flood plain, the ordinance is concerned with protecting the recharge capacity of flood plains and wetlands, and also their distinctive flora and fauna. The philosophy is to utilize such lands in the manner most in conformity with their natural capabilities.

This approach to flood plain management has been given validity by recent court decisions. On March 29, 1974 the Supreme Court of Illinois ruled in Templeton vs. Huss et.al. ruled that no property owner has the right to modify his property to the extent that such modification would increase the flow of surface waters onto another's property beyond a point which could be considered reasonable. The opinion stated:

> "It is obvious, however, that the natural drainage pattern may be substantially altered by surface and subsurface changes which interfere with the natural seepage of water into the soil of the dominant estate...the principle that would prevent unreasonable changes in the natural lateral drainage flow should also apply, in our opinion, to a change which would unreasonably interfere with drainage through natural seepage.
>
> "The question which must be confronted is whether the increased flow of surface waters from the land of the defendants to that of the plaintiff, regardless of whether it was caused by diversion from another watershed, the installation of septic tanks, the grading and paving of streets, or the construction of houses, basements and appurtenances, was beyond a range consistent with the policy of reasonableness of use which led initially to the

good-husbandry exception. The judgment of the appellate court is reversed and the case remanded to the circuit court of Mason County for proceedings consistent with the views here expressed."

The question of what is considered reasonable is something that must be determined individually on a case-by-case basis. Every situation is unique. The court's opinion does, however, articulate a general doctrine: Namely, that the degree of disturbance or improvement of a parcel of land must not be so great that the environmental consequences would be excessive. Such a doctrine shows more respect for the integrity of the natural landscape than has generally been shown in the past.

The Supreme Court of Wisconsin has given specific recognition to the value of flood plain land and wetlands, and declared it in the public interest to protect such land from encroachment. In Just vs. Marinette County (56 Wis. 2d 7), decided October 31, 1972, the Court observed:

> An owner of land has no absolute and unlimited right to change the essential natural character of his land so as to use it for a purpose for which it was unsuited in its natural state and which injures the rights of others.

and

> In the instant case we have a restriction on the use of a citizen's property, not to secure a benefit for the public, but to prevent a harm from the change in the natural character of the citizen's property.

The Wisconsin Supreme Court decision also refers to an opinion of the Supreme Judicial Court of Massachusetts:

"A recent case sustaining the validity of a zoning ordinance establishing a floodplain district is Turnpike Realty Co. v. Town of Dedham (Mass. 1972), 284 N.E. 2d 891. The court held the validity of the ordinance was supported by valid considerations of public welfare, the conservation of 'natural conditions, wildlife and open spaces.' The ordinance provided that lands which were subject to seasonal or periodic flooding could not be used for residences or other purposes in such a manner as to endanger the health, safety or occupancy thereof and prohibited the erection of structures or buildings which required land to be filled. This case is analogous to the instant facts. The ordinance had a public purpose to preserve the natural conditions of the area. No change was allowed which would injure the purposes sought to be preserved and through the special-permit technique, particular land within the zoning district could be excepted from the restrictions."

The Wisconsin opinion, and the Massachusetts opinion referred to above, give legal protection to wetlands and flood plain land. They make their preservation a valid public objective. Such legal reasoning makes it imperative that the environmental costs of filling flood plain and wetland areas be carefully considered in decisions regarding land use activities in these areas.

## VI. REFERENCES


1. Regional Water Supply Report, technical report No. 8, NIPC, 1974.

2. Groundwater Recharge and Runoff in Illinois, Walton, Illinois Water Survey, 1965.

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4. The Future of Groundwater Resources in Du Page County, Groundwater, 1974.

5. Artificial Groundwater Recharge Investigations in NE Illinois, McDonald Sasman, Groundwater, 1967.

6. Living With a River in Suburbia, a report on Salt Creek to the Du Page County Forest Preserve District, Bauer Engineering, Inc. 1974.

7. Report in preparation on Addison Creek Soil Conservation Service, Lisle, Illinois.

8. A Flood Control Plan for Addison Creek, Bauer Engineering, Inc. 1975.

9. Tunnel and Reservoir Plan-Surface Storage Location Alternatives, a report to the Metropolitan Sanitary District of Chicago, Harza Engineering Company, 1973.

10. Environment, Power, and Society, Odum, Wiley Interscience, 1971.

11. Rules and Regulations, Illinois Department of Transportation, Division of Water Resources, Rule 1.1, 1975.

12. Suggested Flood Plain Zoning Ordinance with Commentary, State of Illinois, Department of Local Government Affairs, Sections 4.31 and 4.32, April, 1974.

13. Suggested Flood Damage Prevention Ordinance with Commentary Northeastern Illinois Planning Commission, p. ii, revised December, 1973.

14. Du Page County Zoning Ordinanace, Section IV, J, 2, October, 1974.

Kingery West Flood Retention and Protection Facilities

Forest Preserve District of DuPage County Illinois

Bid:July, 1974

| Contract Items | Quantities | Unit Price | Amount |
|---|---|---|---|
| Demolition | | | |
| Dwellings | 70 | 1,100.00 | 77,000.00 |
| Roadways | 4,650 L.F. | 1.80 | 8,370.00 |
| Earthwork | | | |
| Clear and Grub | 40 A | 800.00 | 32,000.00 |
| Topsoil Removal and Stockpiling | 28,000 $YDS^3$ | 0.75 | 21,000.00 |
| Excavation | 125,833 $YDS^3$ | 1.75 | 188,750.00 |
| Embankment | 112,193 $YDS^3$ | 0.60 | 67,316.00 |
| Structure | | | |
| Reservoir Inlet | 1 L.S. | 4,000.00 | 4,000.00 |
| Reservoir Outlet | | 47,200.00 | |
| Lake Spillway | 1 L.S. | 33,000.00 | 33,000.00 |
| Lake Outlet | 1 L.S. | 16,064.00 | 16,064.00 |
| Waterway Subdrainage | 1,780 L.F. | 7.50 | 13,350.00 |
| Fullerton Detention Basin and Sewer Modification | 1 L.S. | 23,800.00 | 23,000.00 |
| Ellsworth Detention Basin | 1 L.S. | 29,055.00 | 29,005.00 |
| Wrightwood Detention Basin | 1 L.S. | 12,010.00 | 12,010.00 |
| Roadway Reconstruction | | | |
| Fullerton Avenue | 1,500 S.Y. | 6.80 | 10,200.00 |
| Ellsworth Avenue | 785 S.Y. | 5.75 | 4,513.75 |
| Wrightwood Avenue | 640 S.Y. | 5.75 | 3,680.00 |
| Seeding | | 1,050.00 | |
| Riprap | 1,000 C.Y. | 20.00 | 20,000.00 |
| Contingency Items | | | 2,820.00 |
| | | | 566,878.75 |

Hillside Storm Retention Reservoir

Metropolitan Sanitary District of Greater Chicago

Bid: Fall, 1974

| Contract Items | Quantities | Unit Price | Amount |
|---|---|---|---|
| Excavation/Fill | 178,000 C.Y. | $ 2.86 | $509,080.00 |
| Planting | 500 S.Y. | 24.00 | 12,000.00 |
| Sodding | 42,000 S.Y. | 1.69 | 70,980.00 |
| Underdrain | 5,300 FT. | 6.42 | 34,026.00 |
| Berm & Access Ramp Crushed Stone Surfacing 8" | 600 C.Y. | 14.33 | 8,598.00 |
| Fence | 2,750 FT. | 9.82 | 27,005.00 |
| 12" RCP | 450 FT. | 14.44 | 6,498.00 |
| 15"RCP | 210 FT. | 18.10 | 3,801.00 |
| 30"RCP | 390 FT. | 35.90 | 14,001.00 |
| 60"RCP | 15 FT. | 66.67 | 1,000.05 |
| 66"RCP | 45 FT. | 80.00 | 3,600.00 |
| Relocation of 4.5' x 6.5' RCP | 260 FT. | 11.92 | 3,099.20 |
| | | TOTAL.............. | $693,688.25 |

# PREVAILING UNIT COSTS
# FOR
# PLACING RESIDENTIAL FILL
# IN THE
# WESTERN UNITED STATES

March 1975

GENNIS, GRAY & JUSTICE, ENGINEERS
1812 - 14th Street
Sacramento, CA 95814

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# I. INTRODUCTION

The firm of Gennis, Gray & Justice, Engineers, Sacramento, California, was retained by the Hydrologic Engineering Center of the United States Army Corps of Engineers to study prevailing unit costs for placing residential fill in the western United States. This study was conducted by John C. Scroggs and Rudy D. Michon under the general direction of Ivan F. Gennis, RCE8694.

## STUDY OBJECTIVES

The purpose of this study is to aid administrators of the Corps of Engineer's Flood Plain Information Programs in determining the reasonableness of unit costs submitted for residential fill work. Prevailing unit costs were to be obtained from contractors with work experience in placing residential fill. Total quantity of fill material, haul distance, royalty costs, and prevailing labor and equipment rates were to be analyzed with respect to unit fill costs.

## SCOPE

This study is limited in scope to areas within the Western Continental United States. Specifically, these areas include: California, Oregon, Washington, and parts of Arizona and Utah. Prevailing unit costs developed in this study could also be applied to sections of New Mexico, Nevada, and Idaho. A graphical presentation of the study scope is presented in Figure 1.

Unit cost estimates received from contractors and cost engineers were based on prevailing rates in effect during the 1974 construction season. An Engineering News Record Construction Cost Index value of 2072 is therefore considered typical for the unit costs included in this study.


## STUDY AREA BOUNDARIES

## II. METHOD OF APPROACH

### DATA COLLECTION

In general, unit cost information was obtained by telephone conversations with contractors in the western United States study area. In some cases, personal interviews and written correspondence also were used to obtain the necessary unit cost data. Cost engineers from local and district offices of the U. S. Army Corps of Engineers were also contacted to determine unit fill costs used in engineering estimates. Whenever possible, contractors and cost engineers were asked to quote unit costs that were bid or estimated for a particular residential fill job. The conditions of each job; location, haul distance, equipment and labor costs, royalty costs, size of job, and any unique features were also discussed in conjunction with the unit fill cost estimates.

In virtually all discussions with contractors and cost engineers, economy of scale and the haul distance from the borrow area to the job site were two of the most important factors affecting unit costs. To determine the sensitivity of cost for these parameters, those interviewed were first asked to estimate unit costs for residential fill jobs with haul distances of less than 1,000 feet and job sizes ranging from 1,000 cubic yards to over one million cubic yards. Estimates were then obtained for the additional costs corresponding to haul distances greater than 1,000 feet. The form used in compiling cost related data from telephone conversations and interviews is presented in Figure 2.

Table 1 is a summary of the data collected for the residential fill cost study.

# FORM USED IN COMPILING UNIT COST DATA

Contracting Firm ______________________________

Location ______________________________

Discussed Unit Cost Data With ______________________________

Telephone Number ______________________________

| | | | | |
|---|---|---|---|---|
| Size of Job, cu.yd. | | | | |
| Haul Distance, ft.(Miles) | | | | |
| Haul Rate, $/cu.yd.-1,000ft. | | | | |
| Borrow Material Costs, S/cu.yd. (Royalty Costs) | | | | |
| Labor Rates, $/hr. | | | | |
| Equipment Rates, $/hr. | | | | |
| Fill Conditions<br>Water Content % | | | | |
| Compaction % | | | | |
| Surface Relief<br>Site | | | | |
| Borrow Area | | | | |
| Unit Cost, $/cu.yd. | | | | |

NOTES:

FIGURE 2

TABLE 1.
LISTING OF COST INFORMATION

| Area | Unit Cost $/yd^3$ | Size of Job $yd^3$ | Length of Haul (One Way) | Royalty Costs $/yd^3$ | Source of Data | Notes |
|---|---|---|---|---|---|---|
| Los Angeles Area | 1. $1.10 | 4,300,000 | 2.6 miles | -0- | Los Angeles Corps of Engrs. | No moisture control needed |
| | 2. $0.90 | 5,200,000 | 1.0 miles | -0- | Los Angeles Corps of Engrs. | Pervious material |
| | 3. $2.10 | 14,500,000 | 10.0 miles | -0- | Los Angeles Corps of Engrs. | 3 way move (Intermediate Screening Di |
| | 4. $0.65 | 500,000 | -0- Haul Cost $0.005/100-yd^3 after initial mile | -0- | Los Angeles Kirst Constr. | Scrapers |
| | 5. $0.40 | 500,000 | 1000' $0.001/100'-yd^3 to $0.002/100-yd^3 | -0- | Riverside, CA Yeager Constr. | |
| | 6. $0.70 | 250,000 | 1500' | -0- | Riverside, CA Yeager Constr. | |
| Phoenix Area | 7. $1.25 | 500,000 | 1 to 2 miles (short haul) | -0- | Phoenix Tanner Co. | |
| | 8. $1.50 | 500,000 | 1 to 2 miles $0.15/yd^3 mile after 1-2 miles | $0.20 | Phoenix Tanner Co. | |
| | 9. $1.75 | 100,000 | 1 to 2 miles | $0.20 | Phoenix Tanner Co. | For very small job add 15%. |
| S.F. Area | 10. $2.00 | 100,000 | 2 miles | $0.50 | San Carlos,CA Soils Engr. Constr. | Economy of scale not imputant above 100,000 cu. yd. |

TABLE 1. (Cont.)

| | | Unit Cost $/yd^3$ | Size of Job $yd^3$ | Length of Haul (One Way) | Royalty Costs $/yd^3$ | Source of Data | Notes |
|---|---|---|---|---|---|---|---|
| San Francisco Area | 11. | $1.50 | 100,000 | -0- | -0- | San Carlos, CA Soils Engr. Constr. | Scrapers, on site material Fixed costs- $250/piece of equipment |
| | 12. | $1.00 | 100,000 | -0- | -0- | So. San Francisco Warner Constr. | Scrapers |
| | 13. | $1.25 | 50,000 | -0- $.06-.10/mile-$yd^3$ | $0.10-.25 | So. San Francisco Warner Constr. | |
| | 14. | $1.75 | 10,000 | -0- | $0.10-.25 | So. San Francisco Warner Constr. | |
| | 15. | $2.25 | 1,000 | -0- | $0.10-.25 | So. San Francisco Warner Constr. | |
| Portland, Oregon Area | 16. | $1.00 | 500,000 | 1000' | -0- | Portland Peter Kiewet & Son | Costs for dry season work only |
| | 17. | $1.50 | 50,000 | 1000' | -0- | Portland Peter Kiewet & Son | Work during rainy season could be higher than these |
| | 18. | $2.00 | 15,000 | 1000' | -0- | Portland Peter Kiewet & Son | |
| | 19. | $0.72 | 100,000 | -0- 0.14-.16/$yd^3$ mile Scraper 0.24-.27/$yd^3$ mile Truck | -0- | Vancouver, Wash. Jack Budd | Imput material costs are high in Portlanc Cost estimate for wc 1st May-last of Oct. |

TABLE 1. (Cont)

| Area | | Unit Cost $/yd^3$ | Size of Job $yd^3$ | Length of Haul (One Way) | Royalty Costs $/yd^3$ | Source of Data | Notes |
|---|---|---|---|---|---|---|---|
| Portland, Oregon Area | 20. | $0.85 | 100,000 | -0- 0.07-0.08/1000' $yd^3$ after 1st/1000 | -0- | Portland, Oregon R. E. Heintz | |
| | 21. | $0.60 | 500,000 | -0- 0.10-.15/1000'-$yd^3$ | -0- | Portland, Oregon Fred Slate Co. | |
| | 22. | $0.75 | 150,000 | -0- | -0- | Portland, Oregon Fred Slate Co. | No special req., from bid of last January. |
| | 23. | $0.72 | 50,000 | 1000' (or less) | -0- | Portland, Oregon J. W. Presley Co. | Scrapers |
| | 24. | $0.62 | 500,000 | 1000' (or less) (if greater than 1000' .50/$yd^3$ .10-.15/1000'-$yd^3$) | -0- | Portland, Oregon J. W. Presley Co. | Scrapers |
| Salt Lake City, Utah Area | 25. | $0.45 | 50,000 | 1000' (or less) | -0- | Salt Lake City Morrison & Knudson | Scrapers |
| | 26. | $0.28 | 500,000 | 1000' (or less) (if greater than 1000', .03-.04/$yd^3$-1000') | -0- | Salt Lake City | Scrapers |
| | 27. | $0.42 | 50,000 | 1000' (or less) | -0- | Salt Lake City James Reed Co. | Scrapers |
| | 28. | $0.35 | 500,000 | 1000' (or less) | .05-.20/$yd^3$ | Salt Lake City James Reed Co. | |
| | 29. | $0.70 | 50,000 | 1000' (or less) | -0- | Salt Lake City Peter Kiewet & Son | Scrapers |

TABLE 1. (Cont.)

| Area | Unit Cost $\$/yd^3$ | Size of Job $yd^3$ | Length of Haul (One Way) | Royalty Costs $\$/yd^3$ | Source of Data | Notes |
|---|---|---|---|---|---|---|
| Salt Lake City, Utah Area | 30. \$0.55 | 500,000 | 1000' (or less) (if greater than 1000' .09/$yd^3$-1000') | .03-.10/$yd^3$ | Salt Lake City Peter Kiewet & Son | Scrapers |
| | 31. \$0.42 | 100,000 | 1000' (or less) | -0- | Salt Lake City Schocker Co. | Scrapers |
| | 32. \$0.32 | 500,000 | 1000' (or less) (if greater than 1000' .05-.10 $yd^3$-1000') | .03-.25/$yd^3$ | Salt Lake City Schocker Co. | |
| | 33. \$0.70 | 50,000 | 1000' (or less) .12/ton-mile after 1000' | -0- | Salt Lake City W. W. Clyde Co. | |
| | 34. \$0.52 | 500,000 | 1000' (or less) | -0- | Salt Lake City W. W. Clyde Co. | |
| | 35. \$0.60 | 100,000 | 1000' (or less) .10-.12/$yd^3$-mile after 1000' | -0- | Ogden, Utah Gibbon & Reed | Scraper |
| Northern California Coast (not including San Francisco) | 36. \$1.60 | 10,000 | 700' | -0- | Eureka, CA Tom Cory | |
| | 37. \$1.35 | 500,000 | -0- | -0- | Eureka, CA Tom Cory | |
| | 38. \$2.00 | 10,000 | 700' | -0- | Eureka, CA Tom Cory (Information on high bidder for Job listed in 26.) | |

TABLE 1. (Cont.)

| Region | Unit Cost $\$/yd^3$ | Size of Job $yd^3$ | Length of Haul (One Way) | Royalty Costs $\$/yd^3$ | Source of Data | Notes |
|---|---|---|---|---|---|---|
| Northern California Coast (not including San Francisco) | 39. \$0.80 | 500,000 | 1000' (or less) .40-.50/1000' $yd^3$ after 1000' | -0- | Arcata, CA Kadle Constr. Co. | |
| | 40. \$1.20 | 50,000 | 1000' (or less) | -0- | Arcata, CA Kadle Constr. Co. | |
| | 41. \$0.85 | 7,000 | -0- \$2.00/mile $yd^3$ (Tmck) | -0- | Eureka, CA Douglas Melhohn | High water content often boosts cost |
| North-Central California (not including Sacramento) | 42. \$0.35 | 500,000 | 1000' to 1400' | -0- | Michon & Assoc. Redding, CA | |
| | 43. \$1.25 | 10,000 | 1000' to 1400' | -0- | Michon & Assoc. Redding, CA | |
| | 44. \$0.81 | 100,000 | 3300' after 1000' .005/$yd^3$-,00' | -0- | Marysville Earl Parker | |
| | 45. \$2.00 | 15,000 | -0- Truck haul \$0.10/mile-$yd^3$ | \$0.25 | Marysville Earl Parker | |
| Sacramento Area | 46. \$0.60 | 300,000 | 1000' (or less) Add .01-.015/$yd^3$ for each add. 1000' | -0- | Sacramento Ed Mallory | For sandy soils add .08-.12/$yd^3$ for elev diff. greater than 50', add .10-.12/$yd^3$ |
| | 47. \$0.75 | 40,000 to 100,000 | 1000' (or less) | -0- | Sacramento Ed Mallory | For ripping add .20-.25/$yd^3$ |
| | 48. \$0.50 | 500,000 | -0- .005/1000'-$yd^3$ | -0- | Sacramento Luhr Bros. | |

TABLE 1. (Cont.)

Sacramento Area

| | Unit Cost $\$/yd^3$ | Size of Job $yd^3$ | Length of Haul (One Way) | Royalty Costs $\$/yd^3$ | Source of Data | Notes |
|---|---|---|---|---|---|---|
| 49. | $0.80 | 100,000 | -0- | -0- | Sacramento<br>Luhr Bros. | |
| 50. | $0.80 | 500,000 | -0-<br>.12-.15/$yd^3$ mile | -0- | Sacramento<br>Corps of Engineers | |
| 51. | $1.20 | 18,350 | -0- | -0- | Sacramento<br>Repco Constr. | |
| 52. | $1.25 | 5,500 | -0- | -0- | Sacramento<br>Repco Constr. | |
| 53. | $1.50 | 10,000 | -0- | -0- | Sacramento<br>Repco Constr. | |
| 54. | $3.00 | 1,000 | 1 mile | .10 | Sacramento<br>Jim Ferry & Son | |
| 55. | $0.75 | 10,000-50,000<br>avg. 30,000 | 2000' | .10 | Sacramento<br>Jim Ferry & Son | |
| 56. | $0.50 | 500,000 | 2000' | .10 | Sacramento<br>Jim Ferry & Son | |
| 57. | $3.00 | 4,000 | -0- | -0- | Lodi<br>Claude C. Wood Co. | |
| 58. | $3.00 | 16,000 | -0- | -0- | Lodi<br>Claude C. Wood Co. | |
| 59. | $2.00 | 28,000 | -0- | -0- | Lodi<br>Claude C. Wood Co. | |

TABLE 1. (Cont.)

San Diego Area

| Unit Cost $\$/yd^3$ | Size of Job $yd^3$ | Length of Haul (One Way) | Royalty Costs $\$/yd^3$ | Source of Data | Notes |
|---|---|---|---|---|---|
| 60. \$0.75 | 50,000 | 1000' (or less) | -0- | San Diego, CA Horn Constr. Co. | Scrapers |
| 61. \$0.42 | 500,000 | 1000' (or less) (If greater than 1000' .05/$yd^3$-1000') | -0- 0-.10/$yd^3$ | San Diego, CA Horn Constr. Co. | Scrapers |
| 62. \$1.00 | 10,000 to 50,000 | 1000' (or less) | -0- | San Diego, CA Griffith Co. | Scrapers |
| 63. \$0.80 | 500,000 to 1,000,000 | 1000' (or less) | -0- | San Diego, CA | Scrapers |
| 64. \$1.00 | 50,000 | 1000' (or less) | -0- | San Diego, CA B. E. Wilson Construction | Scrapers |
| 65. \$0.85 | 1,000,000 | 1000' (or less) (if greater than 1000', .03/$yd^3$-1000') | -0- .15-.30/$yd^3$ | San Diego, CA B. E. Wilson | Scrapers |
| 66. \$0.85 | 25,000 | 1000' (or less) | -0- | San Diego, CA Calego | Scrapers |
| 67. \$0.55 | 500,000 | 1000' (or less) | -0- | San Diego, CA Calego | Scrapers |

TABLE 1 (Cont.)

| Area | Unit Cost $\$/yd^3$ | Size of Job $yd^3$ | Length of Haul (One Way) | Royalty Costs $\$/yd^3$ | Source of Data | Notes |
|---|---|---|---|---|---|---|
| San Diego Area | 68. $1.25 | 30,000 to 50,000 | 1,000' (or less) | -0- | San Diego, CA Daley Corp | scrapers |
| | 69. $1.20 | 500,000 to 1,000,000 | 1,000' (or less) | -0- | San Diego, CA Daley Corp | scrapers |
| | 70. $1.00 | 50,000 | 4,000' | -0- | San Diego, CA Guy F. Atkinson Co. | scrapers |
| | 71. $1.00 | 500,000 | 4,000' | -0- | San Diego, CA Guy F. Atkinson Co. | scrapers |
| Seattle Area | 72. $2.80 | 230,000 | 3 miles | -0- | Seattle, Wash. Corps of Engrs. | scrapers & trucking |
| | 73. $3.80 | 32,000 | 3 miles | -0- | Seattle, Wash. Corps of Engrs. | scrapers & trucking |
| | 74. $2.15 | 700,000 | 1,000' (or less) (if greater than 1,000', $0.30/yd^3/1,000'$) | -0- | Seattle, Wash. | scrapers |
| | 75. $0.58 | 100,000 | 1,000' (or less) | -0- | Seattle, Wash. Peter Kiewit & Son | scrapers |
| | 76. $0.48 | 500,000 | 1,000' (or less) (if greater than 1,000', $0.12/yd^3-1,000'$) | -0- | Seattle, Wash. Peter Kiewit & Son | scrapers (suspect figures are slanted lower than true cost) |
| | 77. $0.78 | 100,000 | 1,000' (or less) (if greater than 1,000', $0.04/yd^3-1,000'$) | -0- <br> $0.20/yd^3$ | Bellingham, Wash. C. V. Wilder Constr. | scrapers <br> using scrapers using trucks |

TABLE 1 (Cont.)

| Area | Unit Cost $/yd^3$ | Size of Job $yd^3$ | Length of Haul (One Way) | Royalty Costs $/yd^3$ | Source of Data | Notes |
|---|---|---|---|---|---|---|
| Seattle Area | 78. $0.85 | 1,000,000 | 1,000' (or less) | -0- | Seattle, Wash. Northwest Constr. | scrapers |
| | 79. $0.95 | 50,000 | 1,000' (or less) (If greater than 1,000', $0.06/yd$^3$/1,000') | -0- | Seattle, Wash. Northwest Constr. | scrapers (work 6-month per yr only) |
| | 80. $0.68 | 50,000 | 1,000' (or less) | -0- | Seattle, Wash. P. J. Anderson & Son | scrapers |
| | 81. $0.60 | 500,000 | 1,000' (or less) (If greater than 1,000', $0.10/yd$^3$-1,000') | -0- $0.10-.20/yd$^3$ | Seattle, Wash. P. J. Anderson & Son | scrapers |
| Walla Walla, Washington Area | 82. $1.00 | 20,000 | 1,000' (or less) | -0- | Walla Walla, Wash. Walker Excav. Co. | scrapers |
| | 83. $0.80 | 100,000 | 1,000' (or less) (If greater than 1,000', $1.60/yd$^3$ for 1st mile + $0.20/yd$^3$-mile after) | -0- Royalty + hauling 1 mi = $2.00-$2.50/yd$^3$ | Walla Walla, Wash. Walker Excav. Co. | scrapers trucks |
| | 84. $0.88 | 100,000 | 1,000' (or less) | | Walla Walla, Wash Harry Carlyle Excav. | (data of low confidence level) |
| | 85. $0.90 | 30,000 | 1,000' (or less) | -0- | Walla Walla, Wash. Corps of Engrs. | (good data) |
| | 86. $0.70 | 500,000 | 1,000' (or less) (If greater than 1,000', $0.25/yd$^3$-1,000') | -0- $0.15-.30/yd$^3$ | Walla Walla, Wash. Corps of Engrs. | |

## III. FINDINGS

Analysis of the data presented in Table 1 indicates that considerable variability exists among study location estimates for residential fill jobs of similar size and scope. For example, earthmoving and fill placing jobs of 10,000 cubic yards, short haul length, and no royalty costs in San Francisco would probably be bid at \$1.75 to \$1.90 per cubic yard. In contrast, contractors in Salt Lake City would estimate the unit cost for this job at approximately \$0.80. Contractors in Phoenix or San Diego would typically estimate \$1.15 per cubic yard for the same job.

In addition to the disparity of unit costs between cities for similar residential fill jobs of short haul length, considerable variability was found in the haul costs used to estimate jobs with haul lengths greater than 1,000 feet. Contractors in Los Angeles, San Diego, Phoenix, and Sacramento estimate haul costs per cubic yard at approximately \$0.12 to \$0.18 for a one-mile haul distance. Haul cost estimates for the North California coast (Eureka-Arcata area) were as much as ten times higher for the same haul distance.

Based on the above mentioned findings, location within the western United States was established as a significant cost parameter. For the purpose of this study, unit cost data was therefore divided into the following location sub-areas: Los Angeles, San Diego, San Francisco, Sacramento, North California Coast (not including San Francisco), North Central California (not including Sacramento), Phoenix, Salt Lake City, Portland, Walla Walla and Eastern Washington, and Seattle. Earthmoving and fill placing variables affecting unit costs such as economy of scale and haul costs were evaluated separately for each sub-area.

## ECONOMY OF SCALE ANALYSIS

The sensitivity of unit costs to economy of scale was analyzed for each sub-area by adjusting the data compiled in Table 1. All unit costs were normalized for a maximum haul length of 1,000 feet consistent with the prevailing haul rates in each sub-area. Royalty costs were subtracted from these unit costs to arrive at a final adjusted unit cost dependent only on sub-area conditions and the size of the job.

Table 2 presents typical adjusted unit costs for residential fill work in each sub-area. Unit costs are presented for job sizes ranging from 1,000 cubic yards to 1,000,000 cubic yards to show the effects of economy of scale. The derivation of these unit costs for the various job sizes shown was accomplished by graphing the adjusted unit costs against size of job for each sub-area. A sample graph (showing data for Sacramento) is presented in Figure 3.

Since all of the data in Table 2 has been adjusted by the same criteria, relative cost comparisons can be made for the various sub-areas. Weighted unit cost averages, presented in Table 3, have been used to rank the study locations. The North California Coastal area and the San Francisco area consistently displayed the highest adjusted unit cost and were therefore ranked 1 and 2 respectively. The lowest adjusted unit costs in the western United States study area were recorded in the Salt Lake City area.

Unit cost rankings presented in Table 3 appear reasonable when compared to Engineering News Record Construction cost indicies. Indicies for the 1974 construction season list San Francisco with a construction cost index of 2449; Los Angeles with 2147; and Seattle at 1994. Table 3 rankings are also consistent with the prevailing operating engineer wage rates for California counties presented in the Equipment Rental Rates and General Prevailing Wage Rates publication of the California Department of Transportation.

## HAUL COSTS

Although considerable variation was noted for haul costs for the various study sub-areas, contractors in all study locations generally do not assess any haul cost for haul lengths less than 1,000 feet. For haul distances greater than 1,000 feet, haul rates ranged from $0.01 per cubic yard to $0.50 per cubic yard for each additional 1,000 feet. Table 4 lists the haul rate range and average for each study location.

## ROYALTY COSTS

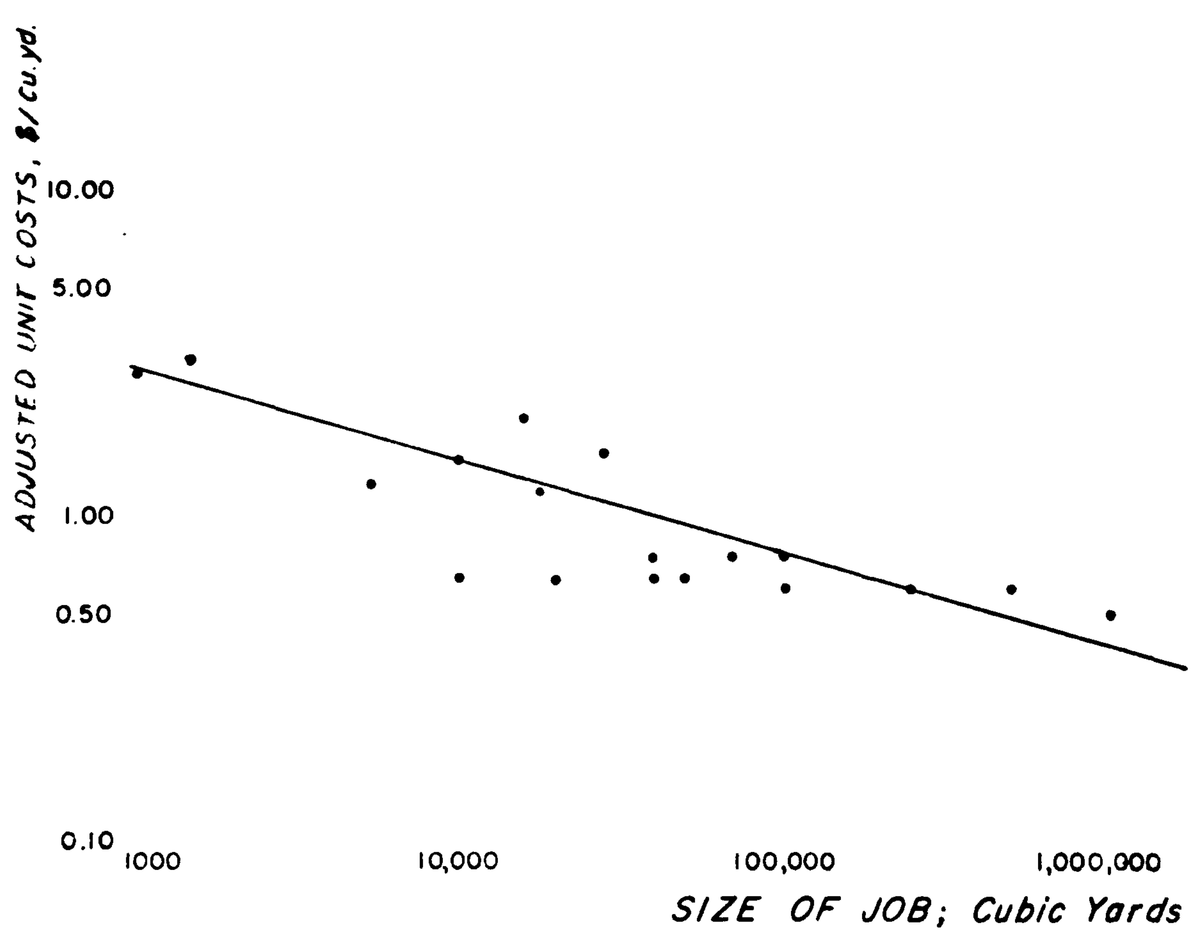
In general, contractors do not have to pay for borrow material used for residential fill. When royalty costs are assessed, however, the amount paid for the material ranges from $0.05 to $0.50 per cubic yard.

No relationship between royalty costs and location within the western United States was observed. In addition, there was no obvious correlation between the borrow material costs and the total quantity of borrow material needed or the haul distance between borrow area and residential fill site.

Study of the factors affecting unit costs indicates that royalty costs are not as critical to unit bids as location, economy of scale, or haul distance. A possible exception to this general rule would occur for large fill jobs with short haul lengths and royalty costs greater than $0.25 per cubic yard.

# SACRAMENTO ADJUSTED UNIT COSTS*

*Haul Distance Less Than 1,000 ft.
No Royalty Costs




SAMPLE ECONOMY OF SCALE GRAPH

FIGURE 3

TABLE 2

ADJUSTED UNIT COSTS*
FOR
STUDY SUB-AREAS

| LOCATION / SIZE OF JOB | LOS ANGELES | SAN DIEGO | SAN FRANCISCO | SACRAMENTO | NORTH CALIF COAST | NORTH CENTRAL CALIF | PHOENIX | SALT LAKE CITY | PORTLAND | WALLA WALLA AND EASTERN WASH | SEATTLE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,000 cu yds | $2.10 | $1.80 | $2.55 | $2.80 | $2.75 | $2.70 | $1.55 | $1.20 | $1.50 | $1.40 | $2.00 |
| 10,000 cu yds | 1.30 | 1.15 | 1.65 | 1.48 | 1.68 | 1.42 | 1.18 | 0.74 | 1.12 | 1.10 | 1.28 |
| 100,000 cu yds | 0.82 | 0.72 | 1.07 | 0.78 | 1.00 | 0.77 | 0.89 | 0.45 | 0.84 | 0.86 | 0.82 |
| 1,000,000 cu yds | 0.52 | 0.46 | 0.70 | 0.40 | 0.62 | 0.42 | 0.68 | 0.28 | 0.64 | 0.68 | 0.52 |

*Haul distance less than 1,000 feet; no royalty cost.

TABLE 3

SUB-AREA UNIT COST RANKINGS

| RANKING | SUB-AREA | WEIGHTED AVERAGE UNIT COST |
|---|---|---|
| 1 | North California Coast | $1.51 |
| 2 | San Francisco | 1.49 |
| 3 | Sacramento | 1.37 |
| 4 | North Central California | 1.33 |
| 5 | Los Angeles | 1.19 |
| 6 | Seattle | 1.16 |
| 7 | Phoenix | 1.08 |
| 8 | San Diego | 1.03 |
| 9 | Portland | 1.02 |
| 10 | Walla Walla and Eastern Washington | 1.01 |
| 11 | Salt Lake City | 0.67 |

TABLE 4

HAUL RATES

| LOCATION | RANGE $/YD$^3$-1,000 FT | AVERAGE $/YD$^3$-1,000 FT |
|---|---|---|
| Los Angeles | $0.01 - $0.05 | $0.03 |
| San Diego | $0.02 - $0.05 | $0.03 |
| San Francisco | $0.01 - $0.02 | $0.02 |
| Sacramento | $0.01 - $0.05 | $0.025 |
| North California Coast | $0.30 - $0.45 | $0.35 |
| North Central California | $0.02 - $0.05 | $0.04 |
| Phoenix | $0.02 - $0.035 | $0.03 |
| Salt Lake City | $0.02 - $0.10 | $0.06 |
| Portland | $0.03 - $0.15 | $0.06 |
| Walla Walla and Eastern Washington | $0.04 - $0.25 | $0.08 |
| Seattle | $0.06 - $0.12 | $0.09 |

# IV. CONCLUSIONS

Unit cost variations for placing residential fill in the western United States is principally dependent on location within the study area, the total quantity of fill material needed, and the required haul distance. To a lesser extent, royalty costs may be an important cost factor for large jobs with short haul distances.

Ranking the study locations as shown in Table 3 takes into account the variations in equipment and wage rates in the western United States. As noted previously, these rankings are consistent with the Twenty Cities Construction Cost Index of the Engineering News Record.

Derivation of unit costs for placing residential fill when no royalty costs are assessed and haul distances are less than 1,000 feet provides a useful analysis of the effects of economy of scale. The dependence of unit costs on the total quantity of fill material needed is shown on Table 2 and the sample graph of Figure 3.

Computation of haul rate averages for the study locations indicates that sub-areas can be grouped together with respect to haul costs. Haul rates for San Francisco, Sacramento, North Central California, Los Angeles, Phoenix, and San Diego all averaged approximately $0.03/cubic yard-1,000 ft. Data presented in Table 4 indicates that $0.075/cubic yard-1,000 ft is a representative haul rate for Salt Lake City, Portland, Walla Walla, and eastern Washington and Seattle. Haul rates received for the North California Coast place this area in a separate, higher haul rate classification.

## UNIT COST NOMOGRAPH

A unit cost nomograph provides an effective means of combining important cost factors in determining the reasonableness of unit bids. The dependence of costs on total quantity of fill material, developed in Table 2, the

ranking of locations with respect to weighted average unit costs shown in Table 3 and the haul rate averages derived in Table 4 have been combined in the development of the unit cost nomograph shown in Figure 4.

Unit costs included in this study are based on an Engineering News Record Construction Cost Index of 2072, the United States average index value for the 1974 construction season. Use of the U. S. average value is appropriate since construction cost index variations for each location have been taken into account by the cost rankings developed in Table 3.

The relative position of sub-areas on the location scale of the unit nomograph corresponds to the cost rankings shown on Table 3. The three haul distance schedules used in the nomograph are consistent with the three typical haul rates found for the western United States study area. Schedule A should be used for residential fill jobs in the San Francisco, Sacramento, North Central California, Los Angeles, Phoenix, and San Diego areas where typical haul costs averaged $0.03/cubic yard-1,000 feet. Schedule B applies only to the North California Coastal area since haul rates in this area were found to be considerably higher than any of the other study locations. Schedule C is applicable to Seattle, Portland, Walla Walla, and eastern Washington and Salt Lake City since haul rates from these areas could be approximated at $0.075/cubic yard-1,000 feet.

A logarithmic scale was used for total quantity of fill material. Use of this scale is appropriate because it provides for the study of a greater range of job sizes. In addition, graphical analysis of unit costs versus job size generally resulted in a straight line relationship when a logarithmic plot was used.

A royalty cost scale was not incorporated into the unit cost nomograph because no correlation could be determined between royalty costs and the other cost factors studied. It is suggested that in checking unit bids with royalty costs this cost (in $/cubic yard) be added to the unit cost derived from the nomograph in Figure 4.

SAMPLE UNIT COST DETERMINATIONS WITH THE UNIT COST NOMOGRAPH

To familiarize the user with the unit cost nomograph, three sample determinations have been shown in Figure 5. The explanation of these sample runs is as follows:

Sample Determination No. 1

Assume that the location of the residential fill work is in the Los Angeles area. The haul distance from the borrow area to the job site is approximately one mile. Fifty thousand cubic yards of fill material are needed. There is no royalty cost associated with the borrow material.

Solution:

With a straight edge, line up Los Angeles on the location scale with a one-mile haul length on haul distance Schedule A. Extend the straight line until it intersects the turning line. Line up the point of intersection with 50,000 cubic yards on the total quantity of fill material scale and read the unit cost.

Answer:

$1.05/cubic yard

Sample Determination No. 2

The residential fill work is to be done along the North California Coast. The haul distance is 1.5 miles and the total size of the job is 10,000 cubic yards. There are no royalty costs involved.

Solution:

With a straight edge, line up the North California Coast point on the location scale with 1.5 miles on haul distance Schedule B. As before, extend the straight line until it intersects the turning line. From the intersecting point, line up 10,000 cubic yards and read the unit cost.

Answer:

$3.98/cubic yard

Sample Determination No. 3

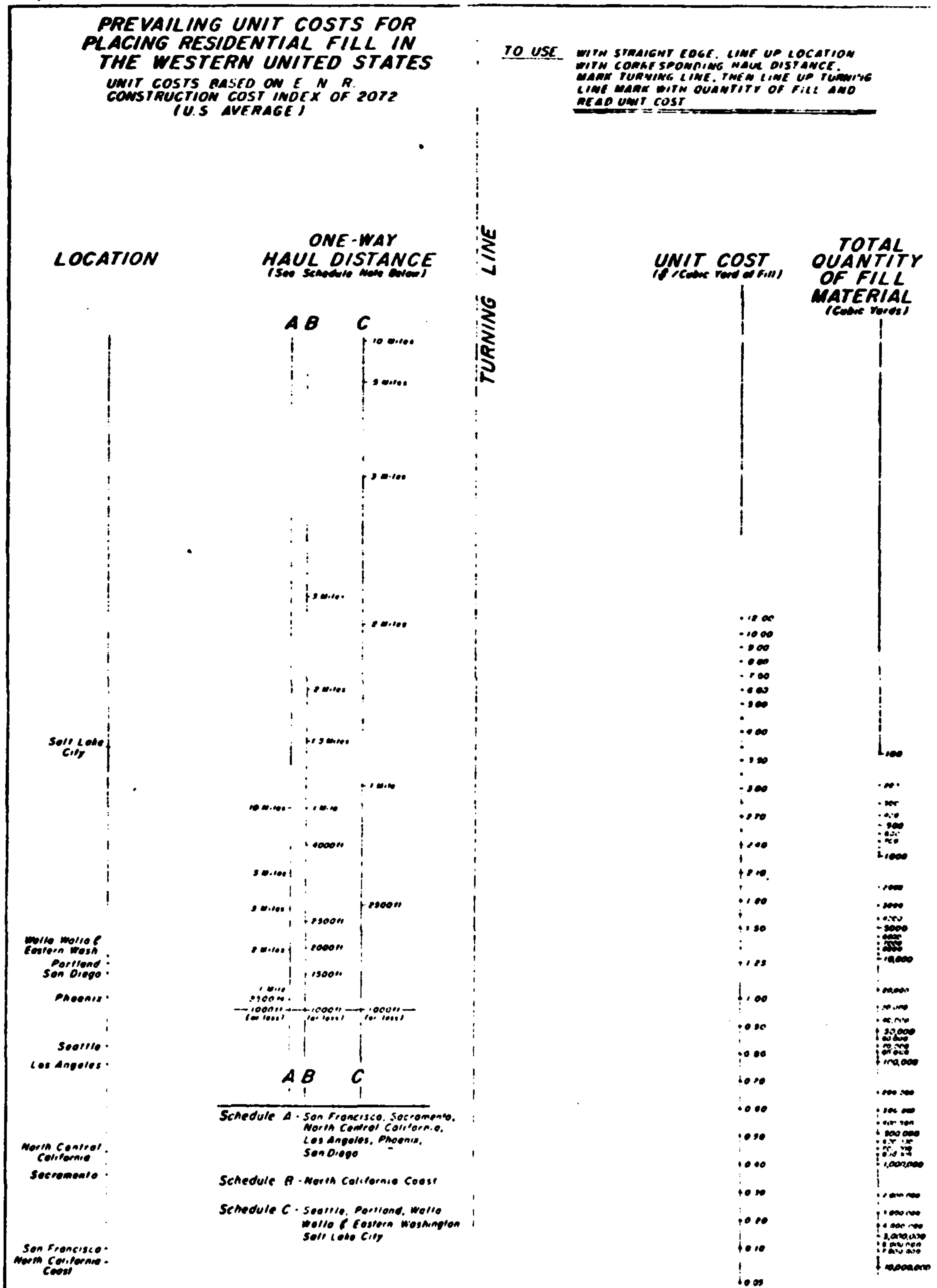
The residential fill work is in the Salt Lake City area. Fill material is readily available near the site (haul distance less than or equal to 1,000 feet); however, a royalty cost of $0.25/cubic yard is assessed. The total quantity of fill material needed is approximately 500,000 cubic yards.

Solution:

Line up Salt Lake City with the 1,000 feet or less mark on haul distance Scale C. Extend the line until it intersects the turning line. From the intersection point find the 500,000 cubic yard mark on the fill material scale and read the unit cost.

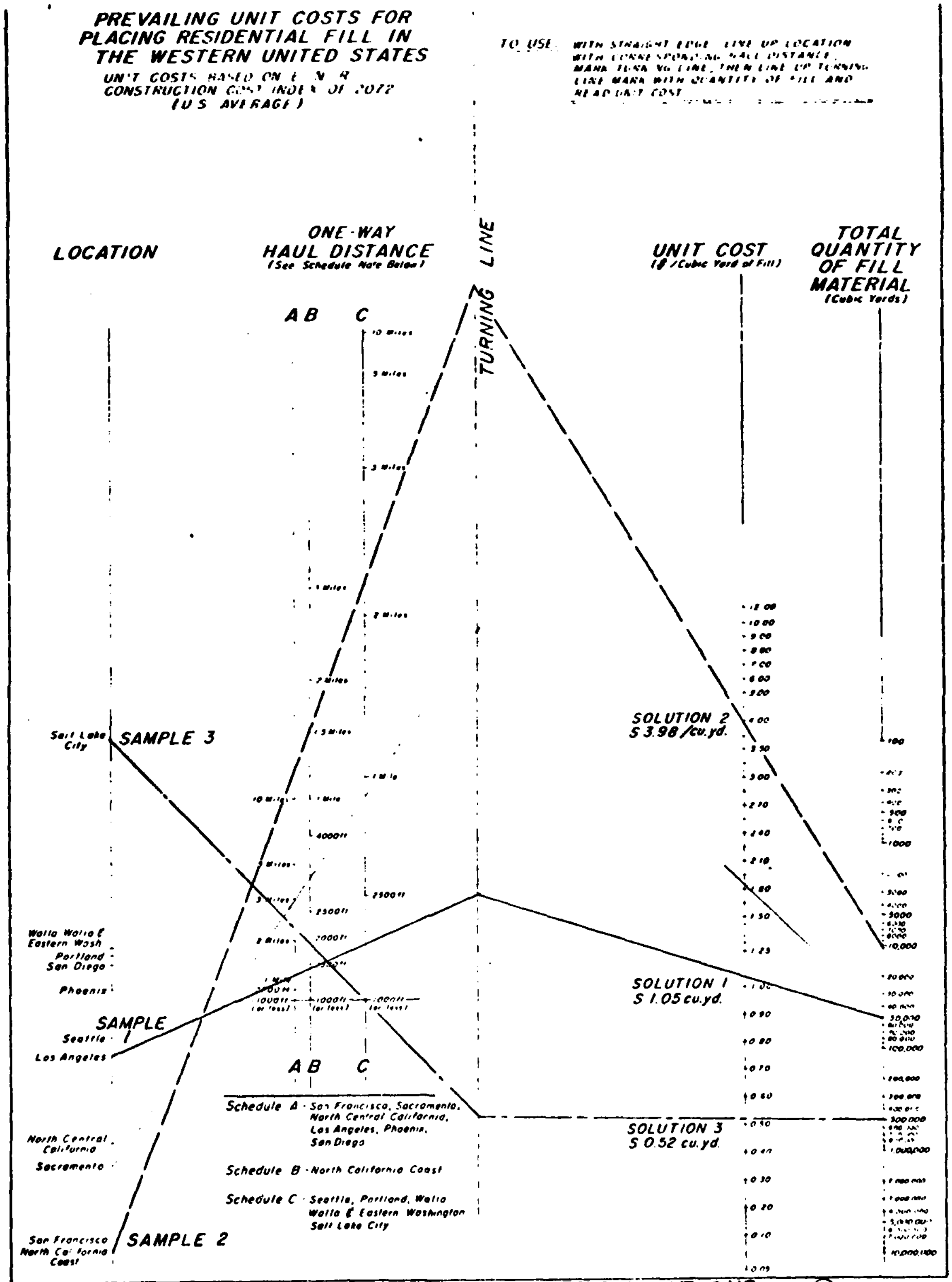
Answer:
$0.52/cubic yard; add $0.25/cubic yard for royalty costs for a unit bid total of $0.77/cubic yard.

In addition to Figures 4 and 5, a mylar original of the unit cost nomograph is provided in the back cover pocket of this report.



PREVAILING UNIT COSTS FOR PLACING RESIDENTIAL FILL IN THE WESTERN UNITED STATES
UNIT COSTS BASED ON E N R CONSTRUCTION COST INDEX OF 2072 (U.S AVERAGE)
TO USE WITH STRAIGHT EDGE, LINE UP LOCATION WITH CORRESPONDING HAUL DISTANCE, MARK TURNING LINE, THEN LINE UP TURNING LINE MARK WITH QUANTITY OF FILL AND READ UNIT COST
LOCATION
ONE-WAY HAUL DISTANCE (See Schedule Note Below)
TURNING LINE
UNIT COST ($/Cubic Yard of Fill)
TOTAL QUANTITY OF FILL MATERIAL (Cubic Yards)
A B C
A B C
Salt Lake City
Walla Walla & Eastern Wash
Portland
San Diego
Phoenix
Seattle
Los Angeles
North Central California
Sacramento
San Francisco
North California Coast
Schedule A - San Francisco, Sacramento, North Central California, Los Angeles, Phoenix, San Diego
Schedule B - North California Coast
Schedule C - Seattle, Portland, Walla Walla & Eastern Washington, Salt Lake City


FIGURE 4




SAMPLE UNIT COST DETERMINATIONS

FIGURE 5

# APPENDIX

## EXTENSION OF UNIT NOMOGRAPH TECHNIQUES
## TO
## EASTERN AND SOUTHEASTERN UNITED STATES LOCATIONS

## V. EXTENSION OF UNIT COST NOMOGRAPH TECHNIQUES TO EASTERN AND SOUTHEASTERN UNITED STATES LOCATIONS

The method of approach used to determine the unit cost nomograph for western United States locations shown in Figure 4 was applied to data obtained for eastern and southeastern U. S. cities. This data, presented in Table 5, indicates that prevailing unit costs for placing residential fill in the east are less than those recorded for the west coast for jobs with haul distances of less than 1,000 feet. Earthmoving and residential fill placing in eastern locations with long hauls are comparable in costs with jobs in western cities because of the generally higher haul rates in effect on the east coast. Data for eastern United States cities was collected by telephone conversations with U. S. Army Corps of Engineers District offices and private contractors.

Consistent with the findings presented in Section III of this report, variability of cost exists among eastern study locations for residential fill jobs of similar size and scope. Haul costs associated with haul lengths greater than 1,000 feet also showed considerable variability. Based on these findings, location, economy of scale, and haul distance were established as significant cost parameters. Unit costs representative of each study location take into account specific local earthmoving and placing conditions such as high water table, poor drainage conditions, limited construction seasons, and local labor and equipment rates. Analysis of economy of scale includes mobilization and demobilization costs important for small earth fill jobs but less significant for large contracts.

The unit cost nomograph developed for the eastern and southeastern United States study areas is shown in Figure 6. Similar in construction to Figure 4, the east coast nomograph indicates that unit costs developed for Savannah, Georgia; Pittsburgh, Pennsylvania; and Chicago, Illinois were the highest among study area locations. San Antonio-Galveston, Texas, and Nashville-Memphis, Tennessee, contributed some of the lowest unit cost bids for the

same study region. The haul distance schedules provided correspond to the various haul rates found. Use of Schedule A is appropriate for checking costs for Philadelphia and Buffalo. These cities recorded the highest haul rates estimated at approximately $0.25 per cubic yard per 1,000 feet of haul up to one mile of haul and $0.15 per cubic yard per 1,000 feet after the first mile. Schedule B, to be used for Pittsburgh, Chicago, Baltimore, and Boston represents a haul rate of $0.15 per cubic yard per 1,000 feet for the first mile with a lower rate of $0.09 per cubic yard per 1,000 feet for longer distances. Determination of haul charges for San Antonio-Galveston, Nashville-Memphis, Savannah, and Huntington (West Virginia) is provided by Schedule C. This schedule corresponds to the lowest haul rate estimated at $\$0.15/yd^3/1{,}000$ feet for the first mile of haul and $\$0.041/yd^3/1{,}000$ feet for longer distances.

To allow for the study of a large range of job sizes, a logarithmic scale was used for the total quantity of fill material axis. Use of this scale is appropriate since graphical analysis of economy of scale factors for each study location resulted in a straight line when a logarithmic plot was utilized. Royalty or borrow material costs were not included in the unit cost nomograph because of the large disparity of values recorded for each location. If royalty costs are applicable on a particular bid, they should be added to the unit cost determined from Figure 6.

Unit cost derived from Figure 6 corresponds to an Engineering News Record Construction Cost Index of 2072. This index value represents the U. S. average during the 1974 construction season, the period from which the unit cost data was recorded.

To update unit costs determined from either Figure 4 or Figure 6, it is suggested that the ratio of the future ENR 20 cities average construction cost index and the index value of 2072 be applied to the values determined from the unit cost nomographs.

TABLE 5

LISTING OF COST DATA
EASTERN AND SOUTHEASTERN UNITED STATES

| State | No. | UNIT COST $/Yd^3$ | SIZE OF JOB $Yd^3$ | LENGTH OF HAUL (ONE WAY) | ROYALTY COSTS $/Yd^3$ | SOURCE OF DATA | NOTES |
|---|---|---|---|---|---|---|---|
| TEXAS | 1. | 0.70 - 1.00 | 50,000 | <1,000' | Ø | H. B. Zachry Co. San Antonio, Texas | Scrapers used; Native clay material difficult to handle; limestone deposits common |
| TEXAS | 2. | 0.60 - 0.90 | 500,000 - 1,000,000 | <1,000' Haul costs, 1,000' .03-.05/$yd^3$/1,000' | Ø | H. B. Zachry Co. San Antonio, Texas | |
| TEXAS | 3. | 2.00 | 1,650,000 | 1 mile (2-mile haul cycle) | Ø | US Corps of Engineers Galveston, Texas District | |
| MISSISSIPPI | 4. | 1.065 | 3,730,000 | 1,200' | Ø | US Corps of Engineers Vicksburg, Miss. District | Data furnished through VTN report |
| TENNESSEE | 5. | 1.25 | 50,000 | <1,000' | Ø | Eatherly Const. Nashville, Tennessee | Costs for dry season only (April through September) |
| TENNESSEE | 6. | 0.80 | 500,000 to $1.0x10^6$ | <1,000' | Ø | Eatherly Const. Nashville, Tennessee | |
| | | | | Haul Costs; <1,000' .06/$yd^3$/1,000' | Borrow Material ranges from 0.05 to 0.50/$yd^3$ | | |

Table 5 Listing of Cost Data, Eastern and Southeastern United States (continued)

TENNESSEE

| | UNIT COST $/Yd^3$ | SIZE OF JOB $Yd^3$ | LENGTH OF HAUL (ONE WAY) | ROYALTY COSTS $/Yd^3$ | SOURCE OF DATA | NOTES |
|---|---|---|---|---|---|---|
| 7. | 0.85 - 1.00 | 50,000 | <1,000' | Ø | McDowell Ent. Nashville, Tennessee | Costs tend to be low in Nashville because of "open shop" conditions; some rock problems are encountered with earthmoving |
| 8. | 0.75 - 0.95 | 500,000 to $1.0x10^6$ | <1,000' | Ø | McDowell Ent. Nashville, Tennessee | |
| 9. | 0.80 - 1.00 | 500,000 | 1,500' (Haul Rate - 1.25-1.50/$yd^3$ for 1st mile >1,000'; 0.20/$yd^3$ each additional mile) | Ø Royalty costs range from 0.30-0.35 per $yd^3$ | McDowell Ent. Nashville, Tennessee | |
| 10. | 1.00 | 50,000 to 500,000 | 1,000 0.10 to 0.17/$yd^3$ for 1,000' >initial 1,000' | Ø | US Corps of Engineers Nashville, Tennessee District | |
| 11. | 1.50 | $1.0x10^6$ | Up to 1/4 mile .15/$yd^3$/mi after 1/4 mile | | Farrell Const. Co. Memphis, Tennessee | Rainfall limits Memphis construction season |

Table 5 Listing of Cost Data, Eastern and Southeastern United States (continued)

| | | UNIT COST $\$/Yd^3$ | SIZE OF JOB $Yd^3$ | LENGTH OF HAUL (ONE WAY) | ROYALTY COSTS $\$/Yd^3$ | SOURCE OF DATA | NOTES |
|---|---|---|---|---|---|---|---|
| GEORGIA | 12. | 2.00 - 2.50 | 5,000 to 25,000 | 1,000' | Ø | US Corps of Engineers Savannah, Georgia | High costs due to high water table conditions and poor drainage |
| | 13. | 1.25 - 1.50 | 500,000 | Up to 1/2 mi (For hauls >1/2 mi, rate 0.15/yd$^3$/mi) | Ø Range 0.10 to 0.25/yd$^3$ | US Corps of Engineers Savannah, Georgia | |
| WEST VIRGINIA | 14. | 1.25 - 1.50 | 50,000 | <1,000' | Ø | US Corps of Engineers Huntington, West Virginia | Rainfall limits construction season |
| | 15. | 1.00 - 1.25 | 500,000 | <1,000 | Ø | US Corps of Engineers Huntington, West Virginia | |
| ILLINOIS | 16. | 2.86 | 178,000 | 1 mile | Ø | Met. Sanitary District Chicago, Ill. | Data provided by USCE Hydrologic Engireering Center |
| | 17. | 1.75 | 125,833 | <1,000' | Ø | DuPoge County Illinois | |
| | 18. | 1.80 | 1,300,000 | 1,500' | Ø | State of Illinois Dept. of Transportation | |

Table 5 Listing of Cost Data, Eastern and Southeastern United States (continued)

PENNSYLVANIA

| | UNIT COST $/Yd$^3$ | SIZE OF JOB Yd$^3$ | LENGTH OF HAUL (ONE WAY) | ROYALTY COSTS $/Yd$^3$ | SOURCE OF DATA | NOTES |
|---|---|---|---|---|---|---|
| 19. | 1.50 to 1.75 | 300,000 | <1,000' | Ø | US Corps of Engineers Pittsburgh, Pa. District | |
| 20. | 2.50 to 2.80 | 300,000 | 5,000'<br>0.35 to 0.60/yd$^3$ 1st mile; .55 to .80 for 2 miles | Ø<br>$1.35 to $2.50/yd$^3$ | US Corps of Engineers Pittsburgh, Pa. District | |
| 21. | 2.10 to 2.50 | 20,000 to 50,000 | <1,000' | Ø | US Corps of Engineers Pittsburgh, Pa. District | |
| 22. | 3.00 to 3.50 | 20,000 to 50,000 | 5,000' | Ø<br>$1.35 to $2.50 per yd$^3$ | US Corps of Engineers Pittsburgh, Pa. District | |
| 23. | 0.75 | 50,000 | <1,000' | Ø | US Corps of Engineers Philadelphia, Pa. District | |
| 24. | 0.60 | 500,000 to $1.0 \times 10^6$ | <1,000'<br>.25/yd$^3$/1,000' | Ø<br>0.25 to 0.30 per yd | US Corps of Engineers Philadelphia, Pa. District | |

Table 5 Listing of Cost Data, Eastern and Southeastern United States (continued)

| State | No. | UNIT COST $\$/Yd^3$ | SIZE OF JOB $Yd^3$ | LENGTH OF HAUL (ONE WAY) | ROYALTY COSTS $\$/Yd^3$ | SOURCE OF DATA | NOTES |
|---|---|---|---|---|---|---|---|
| NEW YORK | 25. | 1.95 - 2.00 | 2,000 | <1,000' | Ø | John W. Cooper Co. Buffalo, N.Y. | Construction limited to 4-month period (mid-May to mid-September) |
| | 26. | 1.95 - 2.00 | 500,000 to $1.0 \times 10^6$ | 1-1/2 miles Rate: 1.10/yd/mi up to 2 mi; .70/yd/mi >2 miles | Ø | John W. Cooper Co. Buffalo, N.Y. | |
| | 27. | 1.75 - 1.80 | 500,000 | <1,000' | Ø | John W. Cooper Co. Buffalo, N.Y. | |
| | 28. | 1.25 | 50,000 | <1,000' | Ø | Frank Huber, Inc. Buffalo, N.Y. | |
| | 29. | 0.80 | 500,000 | <1,000' | Ø | Frank Huber, Inc. Buffalo, N.Y. | |
| MARYLAND | 30. | 3.00 | 5,000 | <1,000' | Ø | US Corps of Engineers Baltimore, Md. District | Mountainous areas prove difficult for earthmoving |
| | 31. | 1.50 - 1.75 | 50,000 | <1,000' | Ø | US Corps of Engineers Baltimore, Md. District | |
| | 32. | 1.30 | 500,000 | <1,000' $0.07/yd^3$/mile | Ø up to $0.25/yd^3$ | US Corps of Engineers | |

Table 5 Listing of Cost Data, Eastern and Southeastern United States (continued)

| | | UNIT COST $\$/Yd^3$ | SIZE OF JOB $Yd^3$ | LENGTH OF HAUL (ONE WAY) | ROYALTY COSTS $\$/Yd^3$ | SOURCE OF DATA | NOTES |
|---|---|---|---|---|---|---|---|
| MASSACHUSETTS | 33. | C.70 to 1.20 | 50,000 | <1,000' | Ø | US Corps of Engineers Waltham, Mass. (Boston) | Construction season limited due to snow and frozen ground conditions. |
| | 34. | 0.80 to 1.00 | 500,000 to $1.0 \times 10^6$ | 1,000' to 1/2 mile | Ø | US Corps of Engineers Waltham, Mass. (Boston) | |

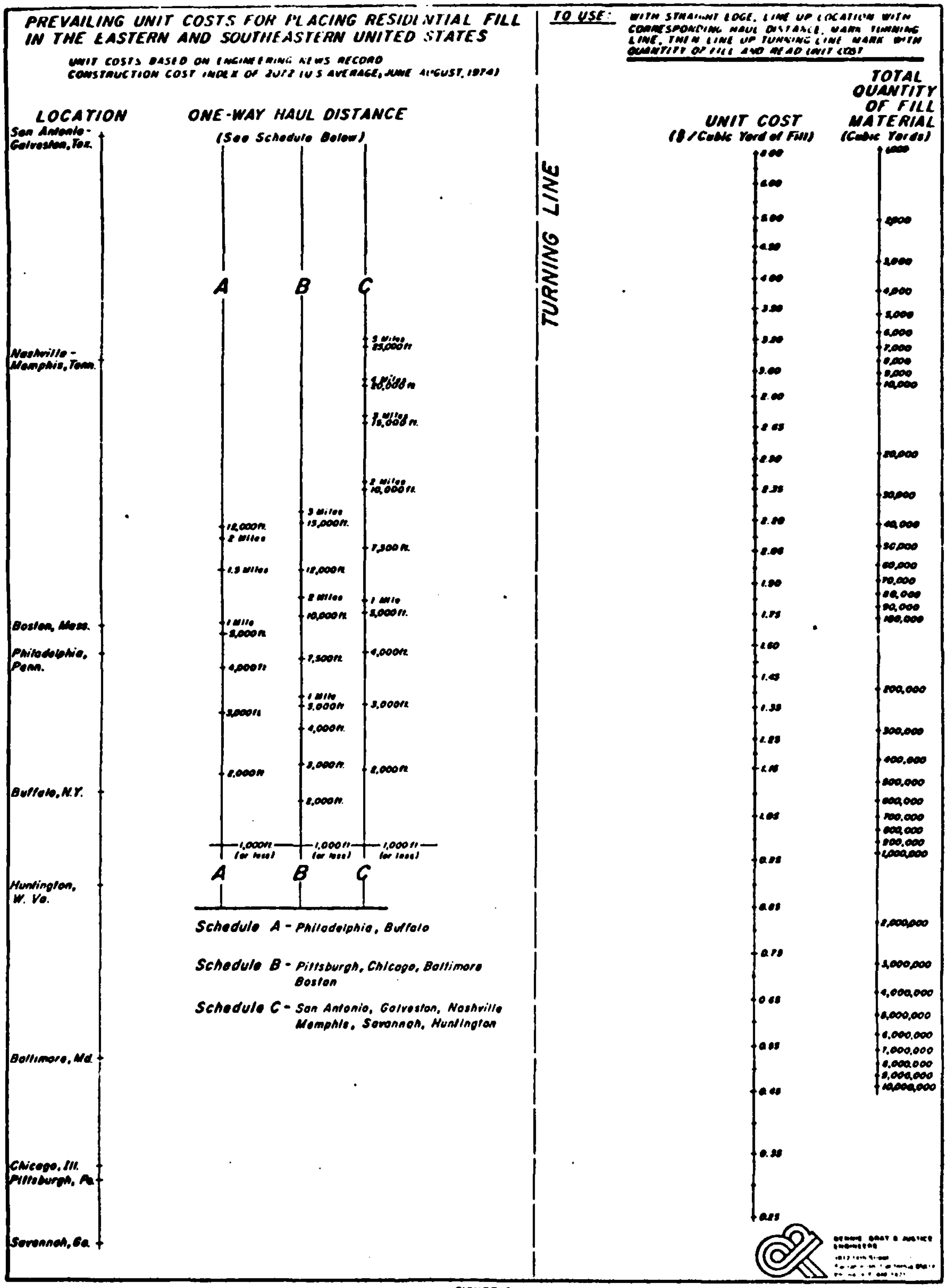

PREVAILING UNIT COSTS FOR PLACING RESIDENTIAL FILL IN THE EASTERN AND SOUTHEASTERN UNITED STATES
UNIT COSTS BASED ON ENGINEERING NEWS RECORD CONSTRUCTION COST INDEX OF 2072 (U.S. AVERAGE, JUNE-AUGUST, 1974)
TO USE: WITH STRAIGHT EDGE, LINE UP LOCATION WITH CORRESPONDING HAUL DISTANCE, MARK TURNING LINE, THEN LINE UP TURNING LINE MARK WITH QUANTITY OF FILL AND READ UNIT COST
LOCATION
San Antonio-Galveston, Tex.
Nashville-Memphis, Tenn.
Boston, Mass.
Philadelphia, Penn.
Buffalo, N.Y.
Huntington, W. Va.
Baltimore, Md.
Chicago, Ill.
Pittsburgh, Pa.
Savannah, Ga.
ONE-WAY HAUL DISTANCE
(See Schedule Below)
A
B
C
1,000 ft. (or less)
TURNING LINE
UNIT COST
($/Cubic Yard of Fill)
TOTAL QUANTITY OF FILL MATERIAL
(Cubic Yards)
Schedule A - Philadelphia, Buffalo
Schedule B - Pittsburgh, Chicago, Baltimore Boston
Schedule C - San Antonio, Galveston, Nashville Memphis, Savannah, Huntington

FIGURE 6

# COST OF EARTHWORK FILLS

# IN FLOODPLAINS OF THE

# CENTRAL AND SOUTHERN UNITED STATES

PREPARED FOR

HYDROLOGIC ENGINEERING CENTER

U.S. ARMY CORPS OF ENGINEERS

APRIL 1, 1975

vtn Engineers Planners Environmental Scientists
2701 Independence Street, Metairie, Louisiana 70002 (504) 455 3881

March 26, 1975

Mr. William K. Johnson
Hydrologic Engineering Center
U.S. Army Corps of Engineers
609 Second Street
Davis, California 95616

RE: Cost Estimating for Earthwork Fills
Constructed Within Floodplain Areas

Dear Mr. Johnson:

VTN is pleased to present this report in fulfillment of our segment of the HEC's nationwide assessment of the cost of earthwork fills constructed within floodplain areas. The report presents the findings of a ten-week inventory and analysis effort. We trust that the HEC's staff will find the base line data and the findings useful in the development of earthwork cost factors for use in Corps of Engineers planning studies.

VTN is very much interested in the results of the studies conducted for the east coast and west coast regions, and in the conclusions of the HEC following coordination of the guidelines from all three studies. We look forward to hearing from you in this regard.

Respectfully submitted,

VTN LOUISIANA, INC.

Terry J. Hartman, P.E.
President

TJH/dw

Enclosures

## TABLE OF CONTENTS

## LIST OF FIGURES AND TABLES

## A. SUMMARY OF FINDINGS.

The purposes of this comparative cost study is to develop costing indices or guidelines to evaluate present and future projects which include earthwork construction in floodplain areas of the central and south-central United States. This report represents these cost guidelines based upon a broad brush, planning level effort, and the findings of a multi-state survey and literature search. This study was conducted in a very short time considering the areal extent of the region studied, and was limited in depth of study by a restricted budget. The background, methodology, present construction trends, and expected projected unit costs utilized to support the cost guidelines are described in the following chapters.

As specified in the Scope of Work for this study, true contract unit prices for earthwork fills in floodplains were analyzed from bid summaries of projects located in the central and southern states, leading to a base unit cost index for earthwork construction by three principal categories: compacted, semi-compacted and hydraulic fills. Unit costs for earthwork construction vary considerably from one construction job to another depending upon size, location, and construction method specified (compacted, semi-compacted or hydraulic). All other factors remaining constant, compacted earthwork construction is consistently the highest unit cost method, requiring additional time and equipment to attain required compaction specifications. Semi-compacted fill is proportionately lower cost, due to a lesser degree of compaction requirements. Hydraulic earthwork fill, on an in-place unit cost basis, is the least cost method of the aforementioned principal construction types.

A graphic index or guideline curve for earthwork fills cost was derived from evaluation of the data collected. This guideline for cost of earthwork fills in floodplain areas (Figure 1), represents a comparison of unit cost of construction by type to size of project, in terms of the quantity of cubic yards. The data was averaged and fitted by manual methods.

The cost of compacted fill is influenced more by project size than the other types; and of course, the smaller the quantity of fill in the project, the higher the unit cost. Semi-compacted and hydraulic fills compare closely, and graphically plane out in a narrow margin cost range in the larger quantity projects. Sharp rises in unit cost are encountered in the moderate to small quantity range of project size.

Regional variations in costs were computed for the central and south-central states, resulting in a subdivision of the generalized study area into southern, central and northern regions of the middle United States. The regional cost variations are based on a comparative study of construction costs in major cities in the three regions, and the comparison is made relative to a base one (base = 1.0 or 100%) for the southern region. A plus four per cent (+4%) cost increase was found for the central region over the southern region and a plus 3 per cent (+3%) cost increase for the northern region over the southern region.

A much greater base of data, i.e., number of construction projects, was accumulated for the south-central states; therefore, this area was designated the base region for establishing current costs for comparison of costs by location, and for forecasts of future costs. Forecasts of the

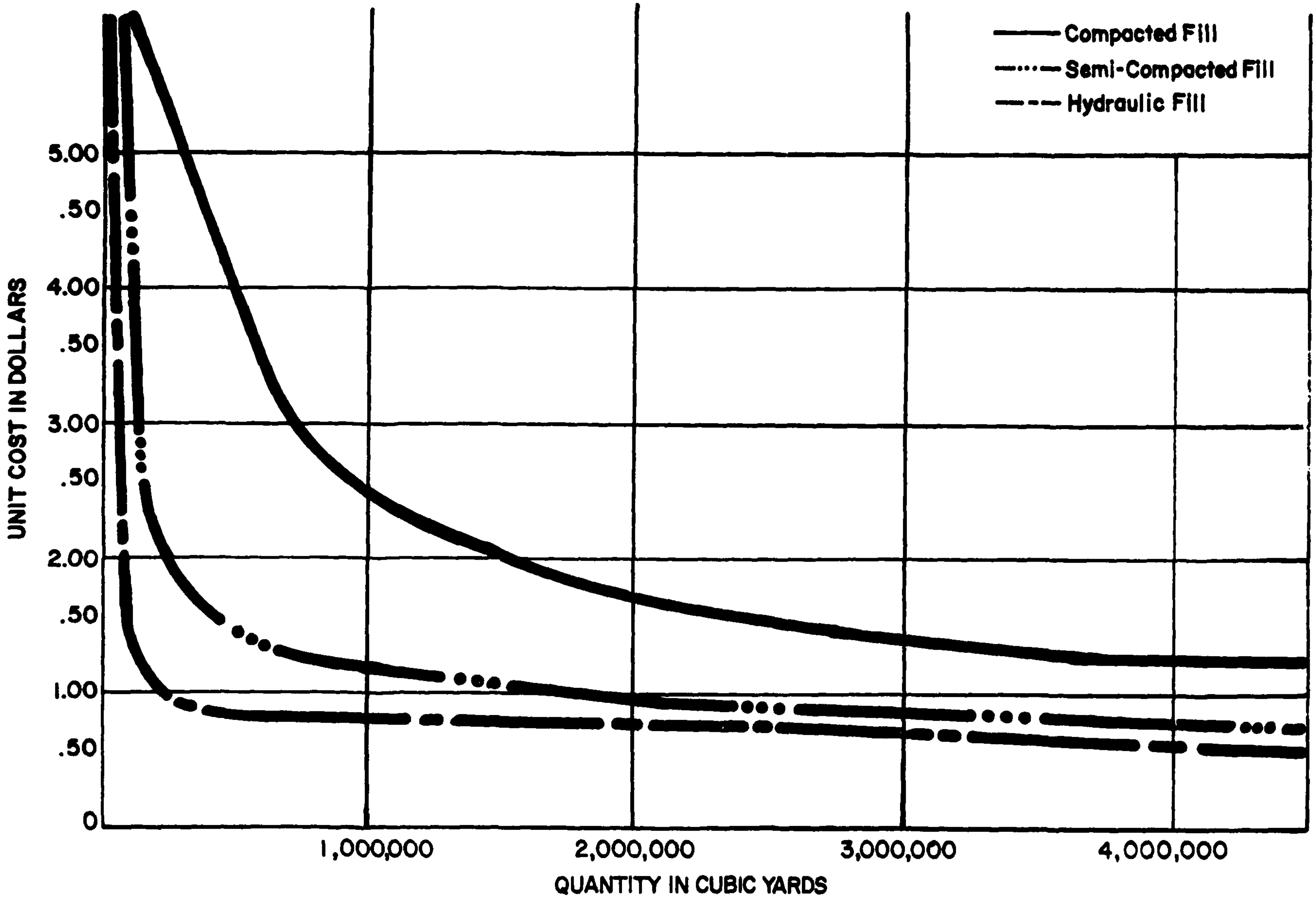



FIGURE 1 - GUIDELINES FOR COST OF EARTHWORK FILLS IN FLOODPLAIN AREAS-1975

future cost of earthwork fills was based upon cost projections to the year 1985, extrapolated from trends of comparative construction costs from the seven year period 1969 to 1975. A conservative forecast results in a minimum annual cost increase of 9.43%. Projected unit costs for earthwork fills, based upon cost data trends from actual projects, were computed by analysis of average unit costs for a variety of projects by size (volume of earthwork) and type, and combined with the regional cost adjustment for location (per cent increase). The forecast annual inflationary cost increase by work location is indicated in Table 1.

TABLE 1

ESTIMATION OF COST INCREASES FOR PROJECT LOCATION AND TIMING

| REGION | REGIONAL INDEX | ANNUAL INFLATIONARY (%) INCREASE |
|---|---|---|
| Southern | Base = 1.0 | 9.43%/yr. |
| Central | +4% = 1.04 | 9.43%/yr. |
| Northern | +3% = 1.03 | 9.43%/yr. |

Utilizing Figure 1 and Table 1 together, a good estimate of order of magnitude costs for future earthwork fill construction in floodplain areas can be obtained. These guidelines can readily serve planners in the determination of future construction costs relative to flood control project features and for assessment of the overall feasibility of project development.

## B. BACKGROUND AND STUDY OBJECTIVES.

In the planning and design of major public works projects for the regulation of stream flow, and in consideration of alternatives which will permit development within floodplain areas, reliable construction cost estimates in conjunction with evaluation of project benefits are very important. Good cost data assures realistic expectations of benefits as determined for project justification. The construction cost data utilized in a benefit-cost analysis may be the key to showing a proposed protective work to be economically justified or not economically justified.

Landowners, local officials and citizen environmental groups also require more accurate data for definition of flood protection project features, particularly when reviewing the economic justification. Structural uses of the floodplain area and improvements such as fill or protective works which make economic uses feasible, rely heavily on good construction cost estimates.

The purpose of this research study is to develop earthwork cost factors intended for use at the planning level, and for use in the development of realistic budget estimates for elements of economic feasibility studies. The data developed is representative of projects located in the central and south-central portions of the United States, as one of three principal regions to be considered by the Corps on establishing the cost of earthwork fills in floodplain areas, and this data is to be coordinated by the Hydrologic Engineering Center with similar data provided by others from eastern and western regions of the United States.

## C. AUTHORIZATION

The Hydrologic Engineering Center, U.S. Army Corps of Engineers, was the sole sponsor of this study as authorized by the Contracting Officer, Mr. D. Lampshire, on purchase order No. DACW05-75-P-1119, dated January 29, 1975. VTN was selected to undertake the study in accordance with the scope of services as described in the Contract Proposal dated December 23 1974. The purpose of the study as stated in the purchase order, is to prepare a written report on the results of a review of reports on floodplain development and economic studies relative to the cost of earthwork fills constructed within floodplain areas, as directed and agreed upon.

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COSTS OF PLACING FILL IN A FLOOD PLAIN.(U)
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## D. STUDY APPROACH.

1) Methodology. Major considerations in the determination of the earthwork fill construction cost estimates for this project included: equipment types utilized in each particular project, soils material types, transport distance, the method utilized in spreading and compacting fills, job output in terms of production in cubic yards per day, and unit costs including all labor, materials and equipment, so that an in-place unit cost was achieved. To assure an accurate unit cost determination for earthwork projects in floodplain regions of the central United States, an obvious approach is the analysis of actual earthwork contracts in various locations within the study area. From the data accumulated for the various types of construction methods associated with earthwork fills, average unit costs were derived. Construction contracts were sorted into three major categories -- compacted, semi-compacted and hydraulic fills.

The limiting factors of time and distance made it essential to obtain a great deal of the data through means of questionnaires relating to earthwork fills on specific projects. The questionnaires were sent to federal. state and local agencies and groups which had direct knowledge of contracts for earthwork construction projects. A copy of the questionnaire utilized is appended to this report. The questionnaire mailing list included 16 Corps of Engineers district offices, 15 state departments of public works, other VTN offices, and 52 offices of the Associated General Contractors.

In some states within the study area, where questionnaires were unable to be answered or returned and data availability was scarce, various sources of published indexes were inventoried and analyzed in regard to earthwork

construction costs. Then data extrapolations were made from these sources to derive representative unit cost figures for those regions.

This study proposes that the central and south-central regions of the United States encompass the area generally described by the states of North and South Dakota, Wyoming, Colorado, New Mexico, Nebraska, Kansas, Oklahoma, Texas, Minnesota, Wisconsin, Iowa, Missouri, Arkansas, Louisiana, Illinois, Mississippi and Alabama (Figure 2). Success in the data inventory tasks of the study was widely varied by area, and the amount of information made available by the return of questionnaires generally varied inversely with the distance from Louisiana, location of the study office. Construction cost adjustment indices for project locations are based upon states or major cities in which the construction is located. The regional cost index was multiplied times the cost estimated for a particular description of earthwork in the southern region, in order to arrive at a cost adjustment for geographical differences of projects in the central and northern regions.

2) Study Depth and Limitations. The scope of the study was broad and complex in terms of the geographical extent, as well as the number of individual construction projects needed to attain a representative overall sample of typical project development costs. Judgment was applied in establishing the depth of the study, or level of detail, suited to the study scope and task assignment. Overall unit cost evaluations were dependent on judgment as supported by evidence from data collections. Specific analysis of every individual project in the total project area and every element of all contracts associated with any earthwork construction was not feasible within the time and budgetary limitations of this study.

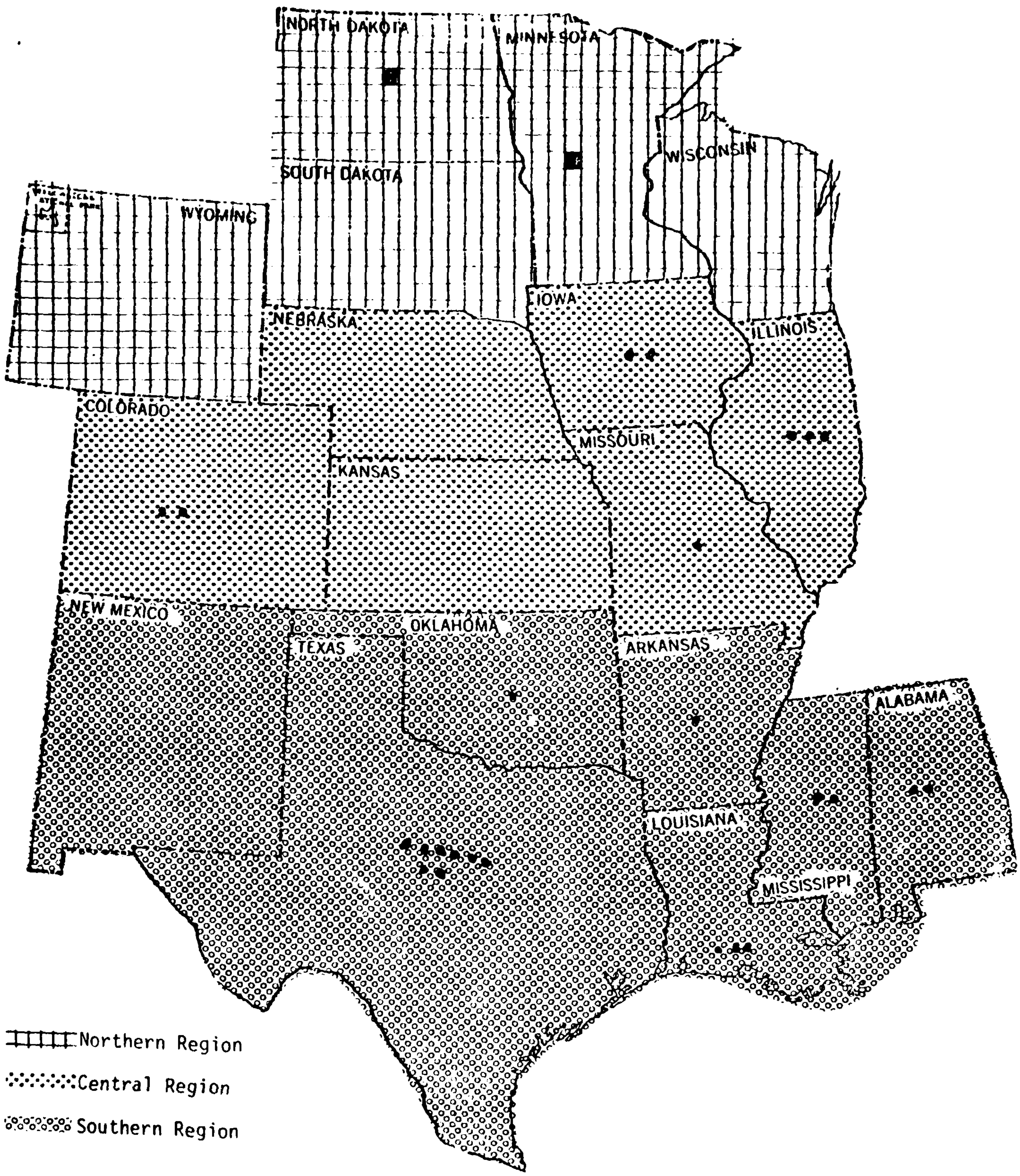


FIGURE 2
STUDY AREA CENTRAL UNITED STATES AND REGIONS OF THE STUDY

E. INVENTORY AND ANALYSIS OF CONSTRUCTION COSTS.

1) Past and Present Cost of Earthwork Fills. Utilizing the bid summary documents for earthwork construction from a number of public projects, located in floodplain areas, and based upon records ranging from 1969 to 1975, the data plotted on Figures 3, 4 and 5 represents an average of unit costs for fill relative to project size. These average projects represent a cross section of typical construction contracts, such as levee embankments, foundation fills, bridge approach fills, and road and highway base fills. A "typical" earthwork project also includes construction procedures common to geographical location and features of a given area, and with production requirements in the accepted range of the various construction types, i.e., hydraulic fills, dragline castings, or material hauling. Projects having unusual circumstances or special conditions were not utilized, i.e., emergency repair work, force account work, extensive foundation preparation, or significant slope protection requirements.

a) Compacted Earthwork Fills. Earthwork construction in floodplain regions generally requires soil compaction requirements of varying degrees. The specific conditions related to the compaction requirements are soil types, geographical location and overall project purpose. The unit cost for compacted earthwork fills in this study represent all measures required to initially transport the materials to the work site, place and shape the materials and all techniques necessary to attain soil compaction requirements. Due to the additional manpower, equipment and time needed for compaction requirements, this type of earthwork has been historically more expensive in unit measurements than the less specific

earthwork construction.

The unit price measurements for a compacted earthwork project are statistically easy to graph in that they generally follow a trend of predictable volume versus unit price relationship. Historically, the larger the project as to cubic yardage measurements, the lower the unit cost of the in-place materials (Figure 3).

b) Semi-Compacted Earthwork Fills. Semi-compacted fill, as used in this report, is defined as earthwork projects requiring limited preparation of deposited materials, such that a minor degree of compaction techniques are required to stabilize the final earth foundation or structure.

In earthwork projects associated with floodplain regions, the majority of semi-compacted earthwork projects consist of some type of levee protection system. The materials are placed on the levee alignment, shaped, and then compacted to a minor degree by associated equipment passing over the materials a given number of times. In this study, the greater number of projects actually reviewed for cost breakdowns were of the semi-compaction types, and records indicate an in-place unit costs much lower than that of a similar project requiring compacted fills (Figure 4).

In reviewing cost data for years where several projects existed in the semi-compacted category, averages of both unit prices and quantities were attained and plotted to indicate general construction trends for a given period (Figure 4). In some cases, individual jobs did not fit the overall base data curve of project unit costs, but it must be understood that contingencies such as the level of general competition for contracts, unusual bid factors, or inaccurate bidding may distort any particular project

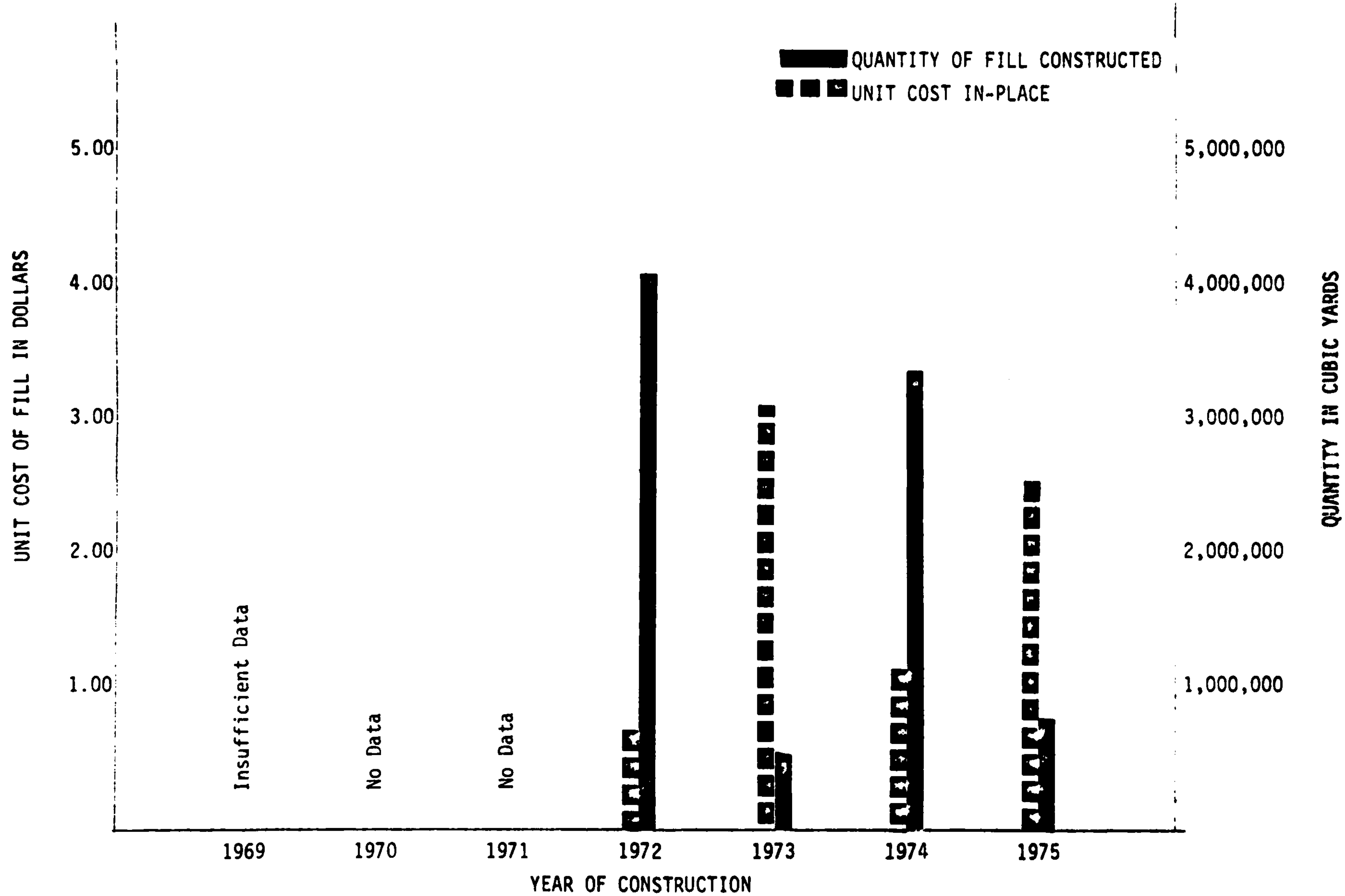


FIGURE 3 - Representative Projects for Compacted Fills

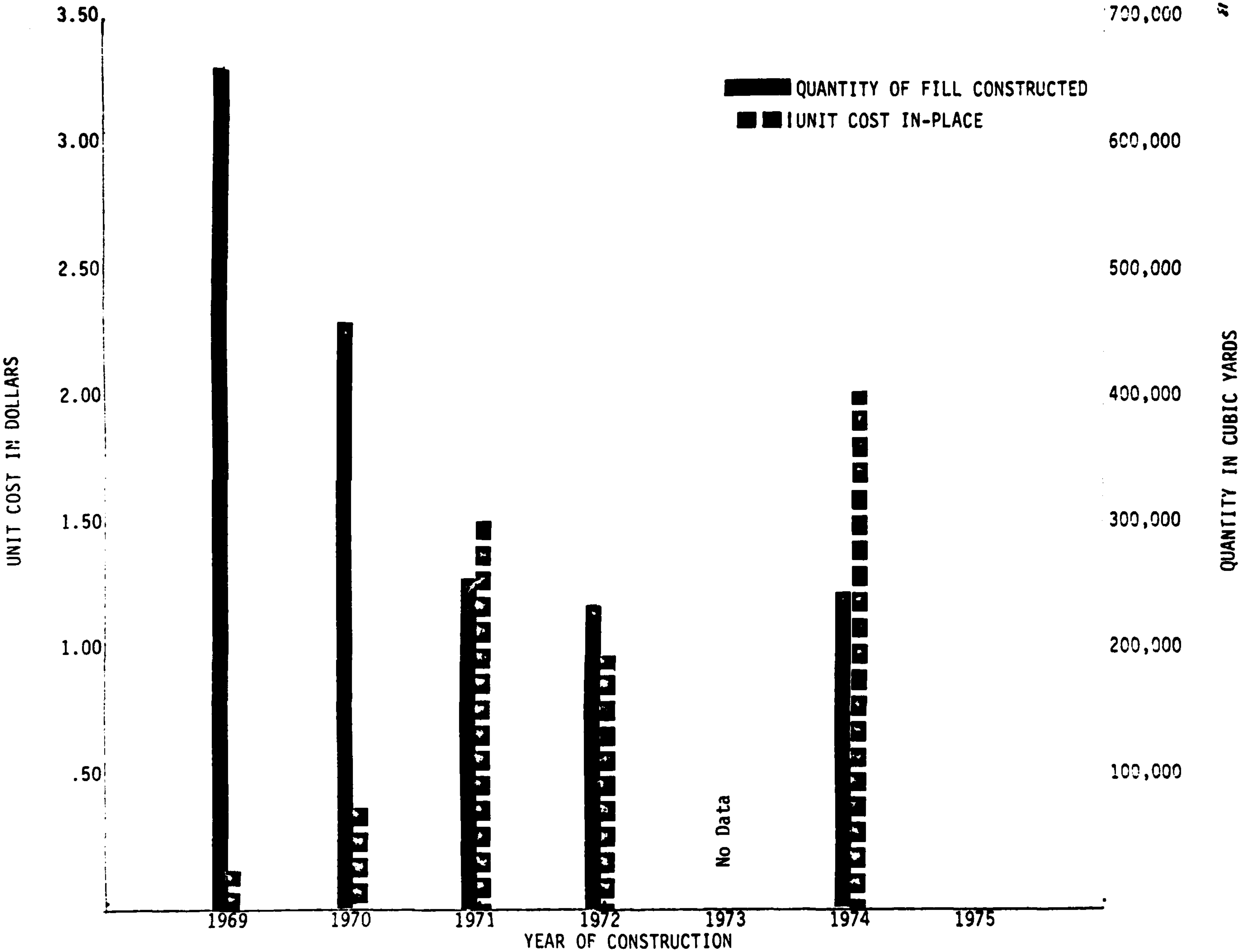


FIGURE 4 - Representative Projects for Semi-Compacted Fills

in relation to the trend of the average of "typical" project represented in Figure 1.

c) Hydraulic Fill. A common alternative to earthwork construction other than the compaction methods is the hydraulic dredging of materials from adjacent waterways. The dredged materials may be placed along the levee alignment or stockpiled for future construction. The hydraulic method of material transport over extended distances has proven desirable in both efficiency and reduced unit cost.

The hydraulic method of earthwork construction is best designed for the larger projects due to the associated cost of mobilization and demobilization of the dredging plant and equipment. Projects ranging under the 30,000 cubic yard mark can usually be done at the same cost or for less by some alternate method of construction such as dragline dredge work or hauling equipment.

In instances where several projects existed in the hydraulic fill category for the same period of time, averages of both the unit prices and the quantities were attained and plotted to indicate general construction trends for a given period (Figure 5). As noted for other earthwork types, individual jobs did not fit the overall base data curve indicating project costs, but it must be understood that contingencies such as the level of general competition for contracts, unusual bid factors, or inaccurate bidding may distort any particular project in relation to the trend of the average or "typical" project represented in Figure 1.

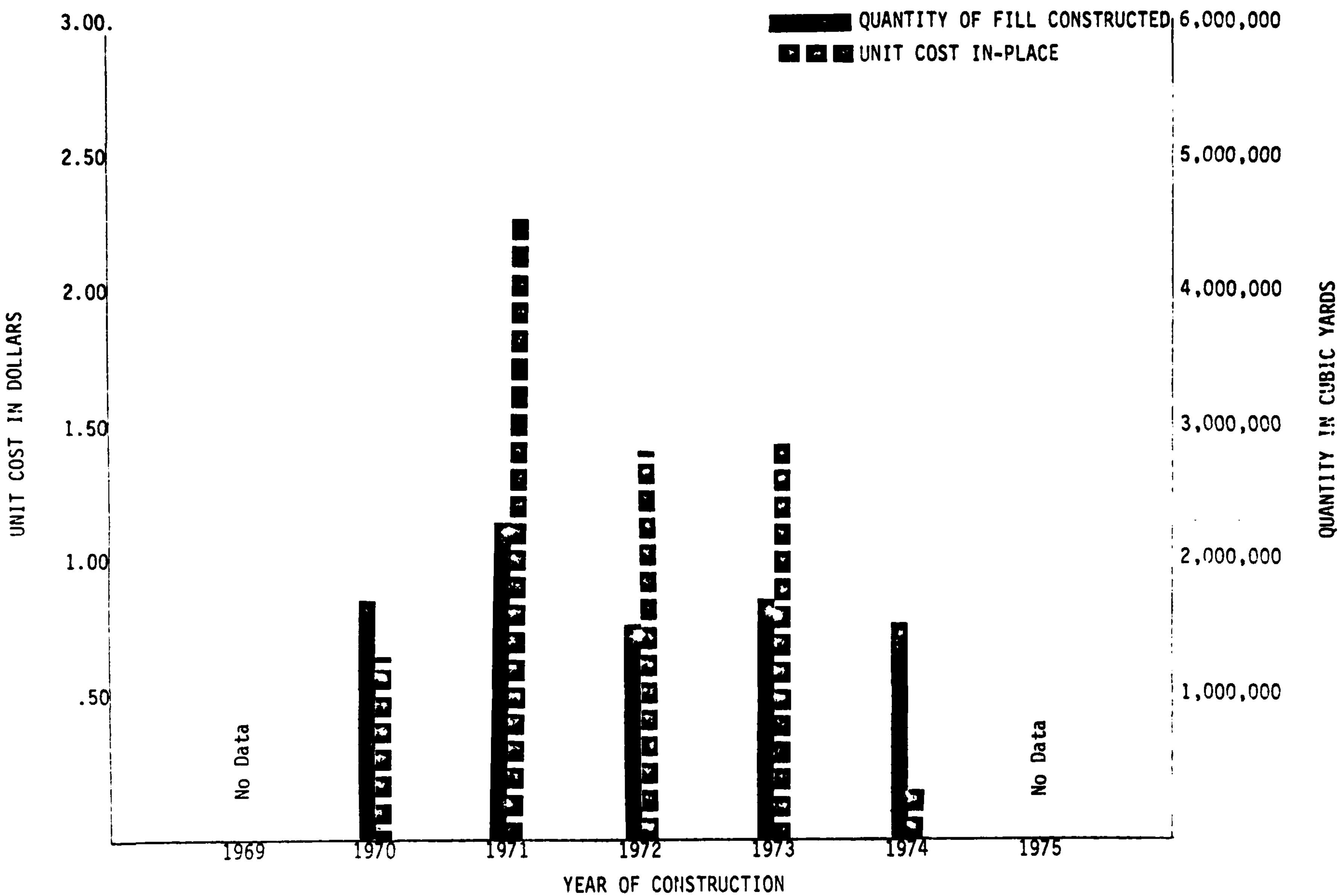


FIGURE 5 - Representative Projects for Hydraulic Fills

d) Regional Variations in Construction Costs. Construction costs in all aspects of earthwork fills are not expected to remain constant throughout the United States. Variations in cost for factors such as labor, materials, and equipment are different as job locations change. Earthwork fill construction is no exception; therefore, regional variations are encountered and can be predicted for given locations, provided a sufficient data bank exists. The project area was subdivided into three main regions: southern, central, and northern (Figure 2).

The scope of this study did not allow an in-depth research of cost factors to adjust for various regions of the project. The approach to cost differences was adapted from researched cost indices published to aid engineers and contractors in preliminary bidding.

Construction cost indexes for all major cities in the study area were compared and a cost index representative of the three study regions was adopted to adjust for varying cost for labor and materials (Table 2). The index for equipment cost variance could not be determined due to the competitive nature of those items. The regional indices are produced to indicate the general cost trends in geographical regions only, and do not indicate actual construction costs.

TABLE 2

REGIONAL INDICES

| DIVISION | LABOR | MATERIALS |
|---|---|---|
| Southern | .78 | .91 |
| Central | .93 | .95 |
| Northern | .87 | .97 |

Source: McGraw-Hill Information Systems Co., 1974
Base of index 1967 = 1.0

From comparisons of actual projects completed of similar nature and in different regions, as well as indices comparisons in the three regions, the conclusion is drawn that the southern states can be operated in with a smaller unit cost, and for comparison reasons will be considered as a base cost of 1 (or 100%). The central states region of this study are the most costly considering that the construction cost of in-place materials averaged 4% higher in comparison with the southern states. These increased costs are attributed to the increase in materials cost as well as labor costs. Figure 1 is representative of base cost and should be extrapolated by 4% to attain unit costs in the central region for the three given construction types.

The northern region exhibited a 3% increase over the in-place unit cost of the southern region. This increase was atributable primarily to an increase in cost of materials. Again, this 3% cost increase should be added to the base cost curves (Figure 1) to attain a unit cost in the northern region.

2) Projecting Cost. Construction costs in general have greatly increased in the last few years, and the immediate future holds no apparent relief for this condition (Figures 6 and 7). The "Engineering News Record" magazine forecast for December 1975 shows an expected 10.7% increase in the ENR construction cost index over December 1974. Earthwork construction is an extremely fluxuating branch of the construction field, and the projecting of any cost index to a given date must be qualified, and the evaluations put into proper perspective.

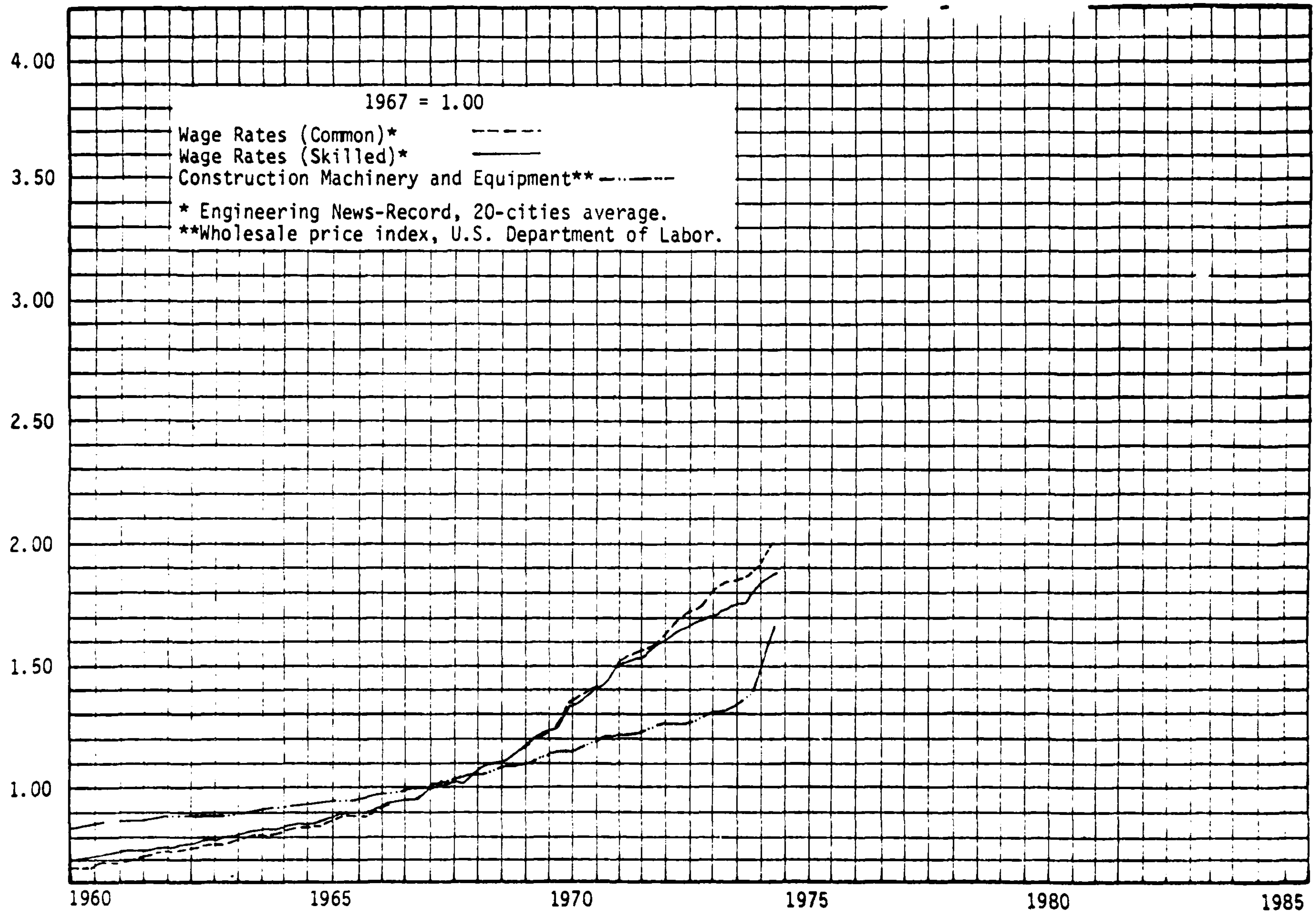


FIGURE 6 - Trends of Labor and Material Cost Indexes

SOURCE: U.S. Department of Interior, Bureau of Reclamation, 1975.

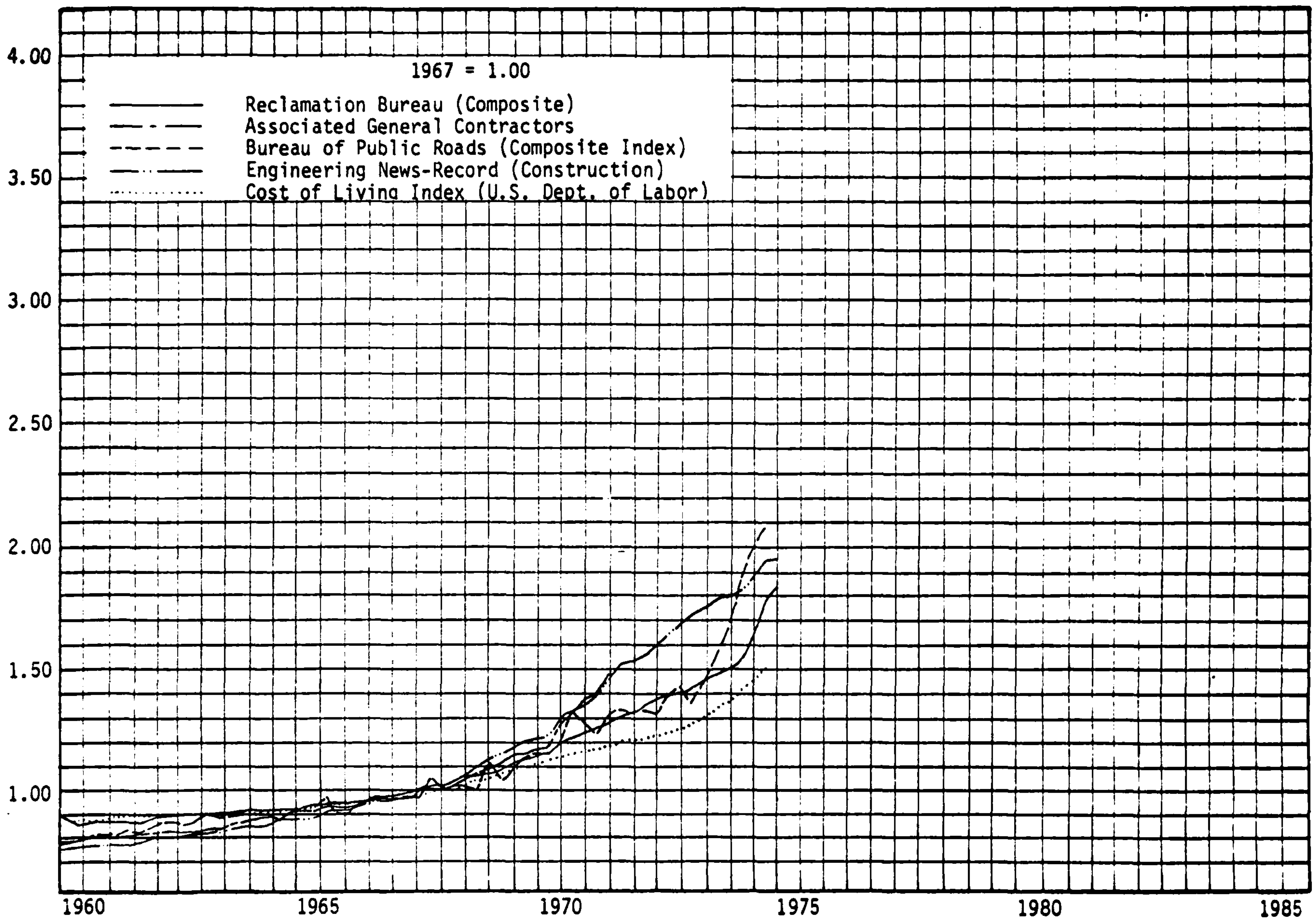


FIGURE 7 - Comparison of Cost Indexes

SOURCE: U.S. Department of Interior, Bureau of Reclamation, 1975.

A composit index of construction cost trends for earthwork fills in floodplains was plotted for the years 1969 through 1975 (Figure 8). The overall increase of construction costs for this period is 66%. This computed is an average annual increase of 9.43%. This average extrapolated in a straight line trend over a ten year projection is also plotted on Figure 8. An earthwork project costing $1.10 per cubic yard in 1969 would cost $3.04 per cubic yard in the year 1985. To forecast the cost of a given project, an adjustment to a point on one of the cost curves (Figure 1) must be made in order to account for the period of time between 1975 and the expected construction date. An annual increase of 9.43% must be added for every year past 1975. Regional variations in construction costs (Table 1) must also be added to the cost for projects located in the central or northern region.

Example:

To estimate the cost of a 1,500,000 cubic yard compacted earthwork project in Iowa, to be constructed in 1980, utilizing the results of this study, the following steps would be

(1) Locate the 1975 Base Cost for a 1,500,000 cubic yard compacted earthwork fill project on Figure 1. . . . . . . . .$2.00/c.y.

(2) 1980 inflation projection of 9.43% @ 4 years (Table 1). . . . 38%

(3) Regional % variation for the central study (Table 1). . . . . 4%

(4) Total cost factor adjustment. . . . . . . . . . . . . . . . . . 42%

(5) Therefore: 1980 unit cost of $2.00/c.y. X 1.42% = $2.84/c.y. or total estimated project cost for earthwork fill = $4,260,000.

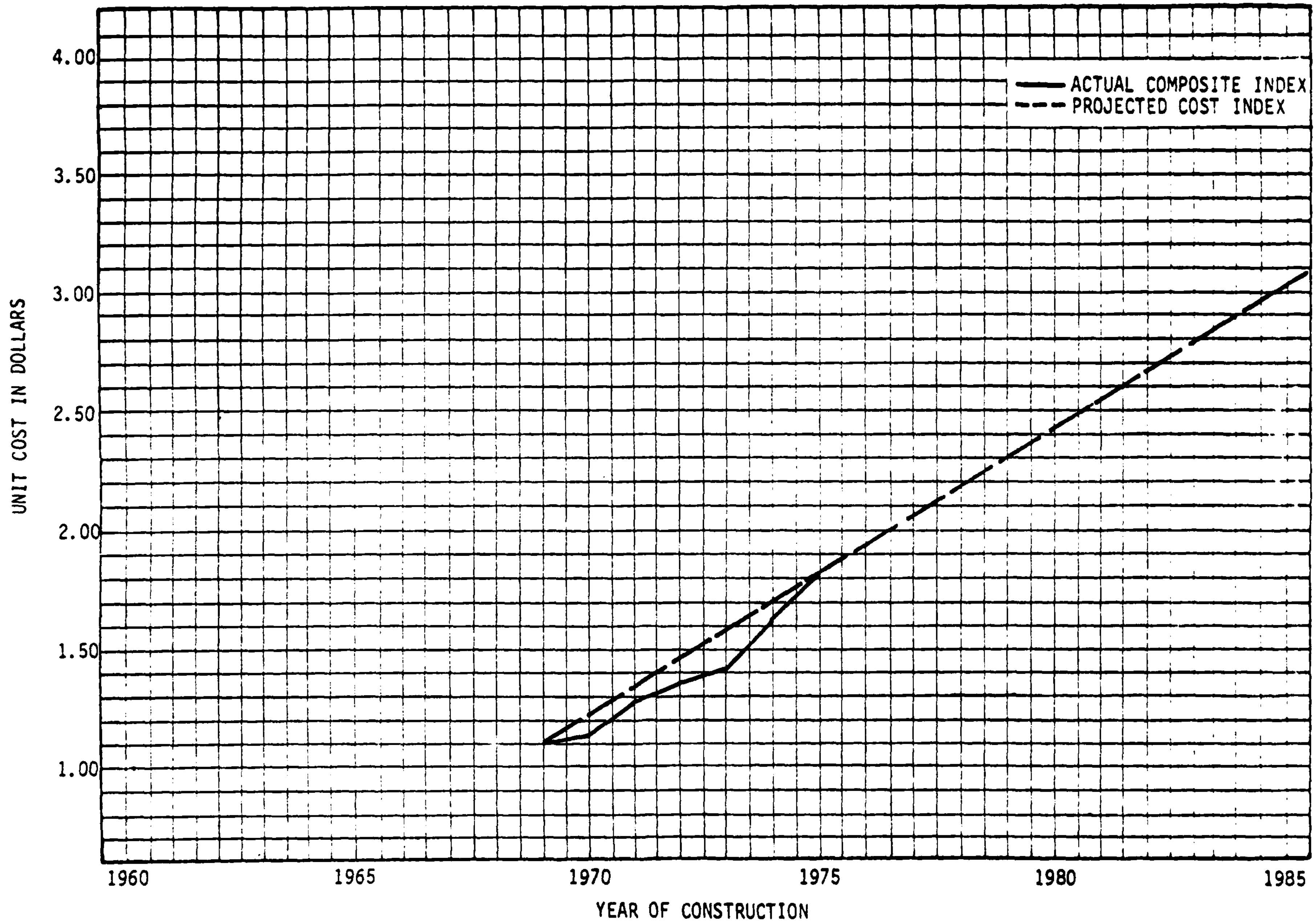


FIGURE 9 - Composite Cost Index of Earthwork Construction in Floodplain Areas, Including Projections to 1985

F. APPENDIX

1) Study Participants

Arnold J. Bernard Contractor (Monroe, Louisiana)

Alvin E. Benike, Inc. (Rochester, Minnesota)

A.S. Horner Construction Co. (Littleton, Colorado)

Ballew & Roberts Construction Co. (Montgomery, Alabama)

E. W. Johnson Construction Co. (Texarkana, Arkansas)

Gerald H. Phipps, Inc. (Denver, Colorado)

Gervais F. Favrot Co., Inc. (New Orleans, Louisiana)

Iowa Natural Resources Council (Des Moines, Iowa)

Illinois Division of Water Resources (Springfield, Illinois)

North Dakota State Water Commission (Bismarck, North Dakota)

P.J. Parker Contractor (Poinsett County, Texas)

Roth & Associates (Storm Lake, Iowa)

Southwestern Industrial Contractors (El Paso, Texas)

State of Mississippi Board of Water Commissioners
(Jackson, Mississippi)

Texas Water Development Board (Austin, Texas)

U.S. Army Corps of Engineers:

Chicago District (Chicago, Illinois)

Galveston District (Galveston, Texas)

Rock Island District (Rock Island, Illinois)

New Orleans District (New Orleans, Louisiana)

Mobile District (Mobile, Alabama)

Fort Worth District (Fort Worth, Texas)

St. Louis District (St. Louis, Missouri)

Vicksburg District (Vicksburg, Mississippi)

U.S. Army Corps of Engineers: (continued)

Little Rock District (Little Rock, Arkansas)

Tulsa District (Tulsa, Oklahoma)

Wiley Hicks, Jr., General Contractor (Amarillo, Texas)

Waco Construction, Inc. (Waco, Texas)

2) References


a) McGraw-Hill Information Systems Company 1974; Dodge Guide for Estimating Public Works Construction Cost

b) U.S. Department of Interior 1975; Construction Cost Trends January 1975 Engineering and Research Center, Office of Design and Construction, Denver, Colorado

c) McGraw-Hill's *Engineering News-Record* 1974-1975

Cost Estimating for Earthwork Fills
Constructed Within Flood Plain Areas

QUESTIONNAIRE

I. DREDGED EARTHWORK FILLS

A. General Description of Project:

1. Location (State and County): ____________________
2. Flood Plain Area (River): ____________________
3. Date (Month and year): ____________________
4. Purpose (Fill constructed for foundation, levee, road, bridge approach, etc.):
____________________

B. Project Specifics

1. Describe equipment type utilized: (Hydraulic or bucket dredges; horsepower or machines; discharge statistics-bucket capacity; reach limitations-lifts; pumping distances, production in terms of cu. yd./day): ____________________
____________________
____________________
____________________

2. Fill soil types: (Describe general soil class, material weights, sieve requirement): ____________________
____________________

3. Describe specified compaction requirements: (Secondary equipment utilized for spreading and grading materials as well as compaction times and methods):
____________________
____________________

4. Describe special conditions ____________________
____________________

C. Construction Costs:

Describe any specific cost breakdowns, when possible, as to individual equipment cost per hour (draglines - dredges-hauling and spreading equipment); specific materials cost (clam shells - rip rap-core materials, fuels) and finally a unit cost of in-place materials per cubic yard with all expenses included: ____________________
____________________
____________________
____________________
____________________

(If you feel attachment of the bid summary will answer this question, please include a copy.)

1. Quantity of total project fill: ____________________ cu.yd.
2. Unit cost of earthwork fill in place: ____________________ ($/cu.yd.)

vtn

II. EARTHWORK FILLS - COMPACTED EMBANKMENT CONSTRUCTION

A. General Description of Project:

1. Location (State and County): ____________________

2. Flood Plain Area (River): ____________________

3. Date (Month and Year): ____________________

4. Purpose (Fill constructed for foundation, levee, road, bridge approach, etc.):

____________________

B. Project Specifics

1. Describe equipment type utilized: (Describe major types of hauling equipment - sizes, carrying capacity, distance of material haul, time/day worked, and production in terms of cu. yd./day): ____________________

____________________

____________________

2. Fill Soil Types: (Describe general soil class, material weights, sieve requirements): ____________________

____________________

3. Describe specified compaction requirements: (Compaction times and requirements): ____________________

____________________

____________________

4. Describe special conditions: ____________________

____________________

C. Construction Costs:

Describe any specific cost breakdowns, when possible, as to individual equipment cost per hour; specific materials cost (clam shells - rip rap (slope protection) core materials - fuels, unit cost of in-place materials per cubic yard with all expenses included: ____________________

____________________

____________________

____________________

1. Quantity of total project fill: ____________________ cu. yd.

2. Unit cost of earthwork fill in place: ____________________ ($/cu.yd.

III. INFORMATION SOURCE

A. The above data was provided by the cooperation of ____________________

____________________

B. This questionnaire was completed by:

Name: ____________________

Telephone: ____________________

Thank you for your cooperation in furnishing the above data.

VTN LOUISIANA, INC.
2701 Independence Street
Metairie, Louisiana 70002
504·455·3881

VTN

DAT
FILM